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NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

MBA PROFESSIONAL REPORT

Medical Equipment Management Through the Use of Radio Frequency Identification (RFID)

By: **Joaquín A. Sánchez,**
Sergio Chávez, and
Richard A. Nixon

December 2004

Advisors: **Nicholas Dew**
Ira Lewis

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The purpose of this MBA project is to identify the potential value of Radio Frequency Identification (RFID) use in the management of medical equipment at Naval Medical Center San Diego (NMCSD). In doing so, our project seeks to derive potential benefits through the use of RFID technology by comparing a group of medical equipment items that are tracked within NMCSD. The project includes a discussion of additional potential uses of RFID infrastructure within the Military Healthcare System, and possible resulting benefits. Ultimately, the project will determine the financial viability and practicality of implementing RFID.

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MEDICAL EQUIPMENT MANAGEMENT THROUGH THE USE OF RADIO FREQUENCY IDENTIFICATION (RFID)

Joaquín A. Sánchez, Lieutenant Commander, United States Navy
Sergio Chávez, Lieutenant, United States Navy
Richard A. Nixon, Lieutenant, United States Naval Reserve

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF BUSINESS ADMINISTRATION

from the

NAVAL POSTGRADUATE SCHOOL
December 2004

Authors: _____
Joaquín A. Sánchez

_____
Sergio Chávez

_____
Richard A. Nixon

Approved by: _____
Nicholas Dew, Lead Advisor

_____
Ira Lewis, Support Advisor

_____
Douglas A. Brook, Dean
Graduate School of Business and Public Policy

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MEDICAL EQUIPMENT MANAGEMENT THROUGH THE USE OF RADIO FREQUENCY IDENTIFICATION (RFID)

ABSTRACT

The purpose of this MBA project is to identify the potential value of Radio Frequency Identification (RFID) use in the management of medical equipment at Naval Medical Center San Diego (NMCSD). In doing so, our project seeks to derive potential benefits through the use of RFID technology by comparing a group of medical equipment items that are tracked within NMCSD. The project includes a discussion of additional potential uses of RFID infrastructure within the Military Healthcare System, and possible resulting benefits. Ultimately, the project will determine the financial viability and practicality of implementing RFID.

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TABLE OF CONTENTS

I. INTRODUCTION....1
A. PURPOSE OF STUDY....1
B. WHAT IS RFID AND HOW DOES IT WORK?....2
1. Active Tags....4
2. Passive Tags....5
C. COURSE OF STUDY....5

II. MILITARY HEALTHCARE SYSTEM....7
A. INTRODUCTION....7
B. DEPARTMENT OF DEFENSE MILITARY HEALTHCARE SYSTEM....7
C. BUREAU OF MEDICINE AND SURGERY (BUMED)....8
D. MISSION OF THE NAVY MEDICAL DEPARTMENT....8

III. HOW WE CAME TO THIS STUDY....11
A. INTRODUCTION....11
B. ANECDOTES....12
C. HOW WE SELECTED THE ITEMS IN OUR BASKET OF GOODS....15

IV. METHODOLOGY....17
A. INTERVIEWS....17
1. Companies Providing RFID Asset Tracking Solutions....17
2. Biomedical Engineering Personnel at NMCSD....17
3. Plant, Property and Equipment (PP&E) Manager at NMCSD....18
4. Comptroller at NMCSD....18
B. PERSONNEL SURVEYED....19
C. WHY NMCSD?....20
D. HOW WE ASSIGNED A DOLLAR VALUE TO ONE WORK HOUR....21
E. ESTABLISHING AN INFRASTRUCTURE COST BASELINE....22

V. RESULTS AND DATA ANALYSIS....25
A. SURVEY RESPONSE....26
B. STATISTICAL ANALYSIS....33
1. Time Analysis of Daily Man-Hours....33
2. Statistical Analysis of Basket of Goods....34
C. RETURN ON INVESTMENT ANALYSIS....39
1. Introduction....39
2. What We Used for Our ROI Analysis....40
3. Baseline ROI Analysis Assumptions....41
a. Baseline ROI Analysis....42
b. Assumption #1 ROI Analysis Based on a 10% Shrinkage-Rate....42
c. Assumption #2 ROI Analysis Based on a 50% Increase In Tags and Readers....43

d. Assumption #3 ROI Analysis Based on a 50% Decrease in Tags and Readers 44
4. Payback Period Analysis 44
5. Our Assumptions about Shrinkage 46

VI. OTHER POTENTIAL USES OF RFID WITHIN A MTF 51
A. PATIENT MEDICAL RECORDS TRACKING 51
B. USAGE OF RFID IN PATIENTS 52
1. Patient Tracking Through RFID 53
a. For Process Improvements 53
b. For Patient Security 54
2. Decreasing the Probability of Medication Errors in Patients 56
C. PHARMACEUTICAL INVENTORY MANAGEMENT 57
D. TRACKING DONATED BLOOD 58

VII. CONCLUSIONS AND RECOMMENDATIONS 63
A. CONCLUSIONS 63
B. RECOMMENDATIONS 63

APPENDIX A. SURVEY 65

APPENDIX B. QUESTIONNAIRES RECEIVED 67

LIST OF REFERENCES 89

INITIAL DISTRIBUTION LIST 91

LIST OF FIGURES

Figure 1. Common Automated Identification Frequency Ranges....4
Figure 2. Respondents rate and pay grade breakdown....26
Figure 3. Respondents rate and pay grade breakout....26
Figure 4. Primary duty of respondents....27
Figure 5. Survey responses to question 3....28
Figure 6. Survey responses to question 4....28
Figure 7. Survey responses to question 5....29
Figure 8. Minutes spent searching for equipment in our basket of goods....30
Figure 9. Survey responses to question 7....31
Figure 10. Survey responses to question 8....31
Figure 11. Frequency that respondent solicited personnel help from other departments..32
Figure 12. Survey responses to question 9a....33
Figure 13. The average daily amount of time spent searching for equipment....34
Figure 14. NMCSD's estimate of equipment mobility and traceability....35

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LIST OF TABLES

Table 1. Monthly pay weighted average calculation 22
Table 2. Survey responses to question 1 26
Table 3. Survey responses to question 2 27
Table 4. Analysis to survey question 4 28
Table 5. Survey responses to question 6 30
Table 6. Survey responses to question 9 32
Table 7. Servey responses to question 9a 33
Table 8. Basket of goods comparison to remaining equipment items 36
Table 9. Annual cost expended searching for items in our basket of goods 37
Table 10. Cost comparison of items in basket of goods to similar items 38
Table 11. Annual cost of man-hours spent searching for equipment 41
Table 12. ROI analysis of baseline model 42
Table 13. ROI analysis assuming a 10% shrinkage rate 42
Table 14. ROI analysis assuming a 50% increase in tag and receiver transmitter costs 43
Table 15. ROI analysis assuming a 50% decrease in tag and receiver transmitter costs 44
Table 16. Baseline scenario payback period 45
Table 17. Assumption #1 scenario payback period 45
Table 18. Assumption #2 scenario payback period 45
Table 19. Assumption #3 scenario payback period 45

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LIST OF ACRONYMS AND ABBREVIATIONS

AMC	Air Mobility Command
AOR	Area of Responsibility
ASD(HA)	Assistant Secretary of Defense (Health Administration)
Auto ID	Automatic Identification
BDC	Branch Dental Clinic
BMET	Biomedical Engineering Technician
BUMED	Bureau of Medicine and Surgery
CAL	Calibration
CNO	Chief of Naval Operations
CO	Commanding Officer
COO	Chief Operating Officer
DBSS	Defense Blood Standard System
DMLSS	Defense Medical Logistics Support System
DoD	Department of Defense
DPAS	Defense Property Accounting System
ER	Emergency Room
FDA	Food and Drug Administration
HF	High Frequency
HM	Hospital Corpsman
ID	Identification
IFF	Identification Friend or Foe
IV	Intravenous
JCAHO	Joint Commission on Accreditation of Healthcare Organization
JMAR	Joint Medical Asset Repository
LCPO	Leading Chief Petty Officer
LF	Low Frequency
MEPRS	Medical Expense and Performance Reporting System
MHS	Military Healthcare System
MTF	Medical Treatment Facility
NAVMEDLOGCOM	Naval Medical Logistics Command
NMCSD	Naval Medical Center San Diego
NPV	Net Present Value
OOD	Officer Of the Day
PM	Preventive Maintenance
PP&E	Property Plant and Equipment
RF	Radio Frequency
RFID	Radio Frequency Identification
ROI	Return on Investment
SECDEF	Secretary of Defense

SH	Ship's Serviceman
TAV	Total Asset Visibility
UHF	Ultra High Frequency
US	United States
USD(AT&L)	Under Secretary of Defense (Acquisition, Technology and Logistics)
USNS	United States Naval Ship

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I. INTRODUCTION

A. PURPOSE OF STUDY

The purpose of this MBA project is to analyze the potential cost benefits associated with the implementation of a Radio Frequency Identification (RFID) infrastructure at Naval Medical Center San Diego (NMCSD) for the management of Property Plant and Equipment assets (PP&E). This study will concentrate specifically with the benefits of attaching active RFID tags to mobile assets. Because there are approximately 13,500 line items that are tracked by the property manager at NMCSD, we have selected to analyze six items identified by NMCSD as being the assets that are more problematic due to their high usage, mobility, safety to patients, pilferability, and constant need for scheduled maintenance/calibration. Potential benefits can be attained from various methods as explained below:

- Man-hours saved by Hospital Corpsman (HM) and medical staff when searching for mobile assets when required for patient use.
- Man-hours saved by property managers and biomedical repair personnel when required to conduct physical inventories or maintenance/calibration of equipment.
- Saved late fees on rental/leased equipment since location will be known when item is due back to the contractor.
- A possible reduction of required equipment due to the ability to automatically record utilization data.
- Cost avoidance of having to replenish stolen assets or items that have been misplaced since an active RFID tag can be integrated to an alarm system.
- Maintain or extend an assets service life cycle due to timely preventive maintenance and calibration of biomedical equipment.

To the best of our knowledge, no other Department of Defense (DoD) Medical Treatment Facilities (MTFs) have implemented RFID to track or manage assets. The

system that comes closest to RFID tracking at MTFs is the use of bracelets at maternity wards to prevent newborn babies from being removed without authorization from a designated area. In the fall of 2003, NMCSD installed the "Halo Infant Protection System" from eXI Wireless Systems, Inc. that actually uses an RFID infrastructure to track newborn babies. The DoD has aggressively embraced the use of RFID to increase Total Asset Visibility (TAV) throughout the supply chain. The Under Secretary of Defense for Acquisition, Technology and Logistics (USD (AT&L)) recently released the latest policy regarding the use of RFID within DoD logistics. In the memorandum, the USD (AT&L) mandates that, "DoD components will immediately resource and implement the use of high-data-capacity-active RFID in the DoD operational environment" to provide global intransit visibility.[1]

Many commercial firms are using RFID to better track mobile assets in order to increase productivity, visibility, and for scheduled preventive maintenance. Several healthcare management service firms have recently focused on RFID as a solution for equipment management. There are thousands of pieces of mobile medical equipment that move around a hospital each day and it is not known whether those assets are positioned for proper usage.[2]

Although RFID technology to track equipment in hospitals is relatively new, and therefore expensive to implement, we feel that there is a possibility that this technology will result in a positive Return on Investment (ROI) to users. This MBA project will analyze RFID infrastructure cost and determine whether the use of RFID for equipment management is financially viable and practicable at NMCSD.

B. WHAT IS RFID AND HOW DOES IT WORK?

RFID, which is also referred to as automatic identification (Auto ID), has been around for over 50 years. It was first deployed by the Royal Air Force (RAF) during the

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[1] Under Secretary of Defense (AT&L), Radio Frequency Identification (RFID) Policy, Version 1.0 30 July 2004

[2] Casey, Michael, "New Technology Focuses on Equipment Management", The MC Report, 8 June, 2004

Second World War as a means to distinguish RAF aircraft from enemy aircraft in a system called identification friend or foe (IFF).[3] The most visible use of RFID today is the automatic toll-payment systems that rely on readers at toll plazas used to scan tags attached to the windshields of passing cars that record the tag's ID and deducts the toll fee from a prepaid account or credit card. RFID technology is now being used to track merchandise as it travels from factory to stores. The military is attaching active tags to pallets and containers shipped to the Persian Gulf in order for logisticians to have the ability to track shipments in the pipeline. The rush to further automate and introduce RFID to the supply chain is a result of Wal-Mart's mandate that will require its top 100 suppliers to use high-frequency tags on cartons and pallets shipped to its stores, and the DoD's similar mandate that will also require RFID tags to shipments by 2005.[4]

A basic RFID system consists of three components; an antenna or coil, a transceiver (with decoder), and a transponder (RF tag), electronically programmed with unique information. An antenna emits radio signals to activate the tag and read and write data to it. Antennas are the conduits between the tag and the transceiver, which controls the system's data acquisition and communication. Antennas are available in a variety of shapes and sizes. They can be built into a door frame to receive tag data from persons or things passing through the door. The electromagnetic field produced by an antenna can be constantly present when multiple tags are expected continually.[5] In essence, RFID is considered the technology that will displace the bar code for product identification. One of the major advantages of RFID versus bar codes is that an RFID tag does not require line-of-sight in order for a product to be read. By capturing data automatically and having the ability to interface with management information systems, RFID creates many opportunities for process improvements within a supply chain, to include inventory and equipment tracking.

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[3] Fanberg, Hank, " The RFID Revolution", American Marketing Association Marketing Health Services, Fall 2004, pp. 43

[4] Want, Roy, "RFID A Key to Automating Everything", Scientific American, January 2004, pp. 60

[5] http://www.aimglobal.org/technologies/rfid/what_is_rfid.asp, 12 November 2004

There are many shapes and sizes of RFID tags in existence today ranging in price from a few cents to several thousand dollars for high-end active tags. Additionally, RFID frequencies operate in a wide spectrum of the available bandwidth and are commonly divided into low (LF), high (HF), and ultrahigh (UHF) and microwave. The read range of RFID tags depends on the frequency at which it operates and whether the tag is passive or active. Below is a table of the common frequencies used for RFID.[6]

Frequency	Regulation	Range	Data Speed	Comments
125-150 kHz	Basically unregulated	≈ 10 cm	Low	Animal identification and factory data collection systems
13.56 MHz	ISM band, differing power levels and duty cycle	< 1 m	Low to moderate	Popular frequency for I.D. Cards (Smart Cards)
433 MHz	Non-specific Short Range Devices (SRD), Location Systems	1 – 100 m	Moderate	DoD Active
860-960 MHz	ISM band (Increasing use in other regions, differing power levels and duty cycle	2 – 5 m	Moderate to high	EAN.UCC GTAG, MH10.8.4 (RTI), AIAG B-11 (Tires), EPC (18000-6')
2450 MHz	ISM band, differing power levels and duty cycle	1 – 2 m	High	IEEE 802.11b, Bluetooth, CT, AIAG B-11

Figure 1. Common Automated Identification Frequency Ranges

1. Active Tags

Active RFID tags are powered by an internal battery and are typically read/write, i.e., tag data can be rewritten and/or modified. An active tag's memory size varies according to application requirements. Some systems operate with up to 1MB of memory. The battery-supplied power of an active tag generally gives it a longer read range. The trade-off is greater size, greater cost, and a limited operational life (which may yield a maximum of 10 years, depending upon operating temperatures and battery type).

[6] Ibid

2. Passive Tags

Passive RFID tags operate without a separate external power source and obtain operating power generated from the reader. Passive tags are consequently much lighter than active tags, less expensive, and offer a virtually unlimited operational lifetime. The trade-off is that they have shorter read ranges than active tags and require a higher-powered reader. Read-only tags are typically passive and are programmed with a unique set of data (usually 32 to 128 bits) that cannot be modified. Read-only tags most often operate as a license plate into a database, in the same way as linear bar codes reference a database containing modifiable product-specific information.[7]

C. COURSE OF STUDY

There have been two MBA professional reports recently completed at the Naval Postgraduate School (NPS) that dealt with the use of RFID.[8] In both cases the studies dealt with the impact of RFID in the logistics chain. The DoD's goal is for TAV of all cargo being shipped to the Persian Gulf Area of Responsibility (AOR) to better support the warfighter when it comes to logistics support. The MBA professional report completed in June 2003 concentrated on the Air Mobility Command (AMC), which is the organization responsible for all military transportation, and what it would take to comply with the mandate of the USD (AT&L) to support an RFID infrastructure at aerial ports and major points of embarkation and debarkation to ensure that RFID data was being properly captured and logistics data servers updated accurately. The MBA professional report completed in June 2003 concentrated on what a Supply Officer was willing to pay per requisition in order to have visibility of individual shipments throughout the supply chain with the aid of RFID and logistics data servers.

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7 Ibid.

8 The previous RFID MBA projects were completed in December 2003 and June 2004. See:

Hozven, Marcelo and Clark, George, "DoD Supply Chain Implications of Radio Frequency Identification (RFID) Use Within Air Mobility Command (AMC)," MBA Professional Report, Naval Postgraduate School, December 2003

Corrigan, Christopher and Kielar, Jayson, "The Value of Logistics Information to the Warfighter," MBA Professional Report, Naval Postgraduate School, June 2004

We are aware of the benefits RFID can have in a supply chain, but our study will concentrate on the use of RFID within an MTF, and specifically, NMCSD for equipment management. Civilian hospitals are beginning to use RFID to track assets for improved visibility, utilization, and prevent capital expenditures due to loss or theft. While the cost to implement the required infrastructure may seem high, preliminary results at civilian hospitals show that a positive return on investment can be attained due to less shrinkage, fewer rentals, and better staff productivity.[9] Obviously, civilian hospitals are always searching for ways to improve profit margins and customer service. By adopting RFID, civilian hospitals intend to increase their profits by maximizing asset utilization, reducing equipment expenditures, and increasing customer service by tracking patients to identify bottlenecks in their processes. Since military hospitals are not concerned with profit margins, we will concentrate on possible cost reductions and improved equipment management to determine the financial viability and practicality of launching an RFID infrastructure at NMCSD.

Furthermore, patient safety has become a big issue in the healthcare industry and an RFID infrastructure offers the ability to find critical assets that require timely maintenance/calibration, which will result in improved patient safety. Patient safety is something that cannot be financially measured (unless litigation is involved), but is something that hospitals always strive to improve.

[9] Michael Casey, "New Technology Focuses On Equipment Management," The MC Report, 8 June 2004. http://www.trenstar.com/agility/news/mc_report.asp

II. MILITARY HEALTHCARE SYSTEM

A. INTRODUCTION

Healthcare costs in the United States (US) have continued to rise throughout the last decade and do not show any sign of slowing down. There are many advocacy groups calling for reductions in healthcare costs. There have been many efforts to control these skyrocketing costs, and these efforts will continue far into the future until they can be brought under control. One of the main reasons for rising healthcare costs and of great concerns within the US healthcare system is the rising cost of medical equipment. An additional concern is the proper maintenance of all medical equipment. We see RFID as a potential technology that can help alleviate both of these issues.

We usually can't get through the daily newspaper or evening news without there being a story on rising healthcare costs. How can this be controlled? What can be done to prevent this from happening? Or is this just a part of doing business, and something with which we'll just have to live?

The Military Healthcare System (MHS) is also very concerned with rising healthcare costs. The MHS has been trying for many years to compare itself to its civilian counterpart. This has proven to be a much harder task than originally thought. However, throughout this process, the MHS has learned some valuable lessons in trying to compare itself to the civilian healthcare sector. Nevertheless, Navy Medicine seems to have taken the lead in trying to measure its performance and in implementing cost-controlling measures, thus developing a "yardstick" that can be commonly applied throughout Navy Medicine, which will eventually lead to a favorable comparison to the civilian medical community.

B. DEPARTMENT OF DEFENSE MILITARY HEALTHCARE SYSTEM

The Assistant Secretary of Defense for Health Affairs (ASD (HA)), is responsible for overall supervision of the health and medical affairs of the DoD. He serves as the principal staff assistant and advisor to the Secretary of Defense (SECDEF) for all DoD

health policies, programs, and activities, and subject to the direction of the SECDEF, exercises oversight of all DoD health resources.

The DoD manages its Healthcare through the Office of ASD (HA). The primary role of the ASD (HA) is to ensure the nation has available at all times a healthy fighting force supported by a combat-ready healthcare system, and to provide a cost-effective, quality health benefit to active duty members, retirees, survivors, and their families. The MHS has the responsibility of providing healthcare to over 8.9 million beneficiaries through a $28 billion healthcare system, consisting of a worldwide network of 76 military hospitals, over 500 military health clinics, and the Department's civilian sector network partners.

C. BUREAU OF MEDICINE AND SURGERY (BUMED)

Each military branch (Army, Air Force and Navy (Marines fall under the Navy for healthcare)) has their own respective Surgeon General, who manages their healthcare. For the Navy, he also serves as the Chief of the Bureau of Medicine and Surgery (BUMED).[10] The Bureau of Medicine and Surgery (hereinafter referred to as BUMED, Navy Medical Department and/or Navy Medicine) is the headquarters of the Navy Medical Department. It is headed by a Medical Corps admiral, known as the Chief, BUMED, dual-hatted as the Surgeon General of the Navy. Falling under the command of the Chief of Naval Operations (CNO), Chief, BUMED commands BUMED and shore activities as assigned by the CNO.

D. MISSION OF THE NAVY MEDICAL DEPARTMENT

The Navy Medical Department is comprised of the Medical Corps, Dental Corps, Medical Service Corps, Nurse Corps, Hospital Corps, and the Dental Technicians. Navy Medicine's main mission is to administer the commands and facilities that provide medical and dental services to active-duty service members and other eligible

[10] Authors note: BUMED, as an enterprise, is also referred to as Navy Medicine

beneficiaries, as well as the activities under the BUMED, and other medical and dental departments of other major claimants and offices.

Furthermore, Navy Medicine is comprised of many small medical clinics, several medium-size hospitals, and three large teaching medical centers (Bethesda, Portsmouth, and San Diego). Additionally, Navy Medicine is responsible for providing dental care though several Dental Centers. Navy Dentistry is comprised of a support staff at BUMED, and is organized in seven regional organizations called Dental Centers, spread out all over the US and four Dental Centers overseas. Within each of these Dental Centers there are several smaller dental clinics called Branch Dental Clinics (BDC). Their size will be determined by their respective geographical location and the support mission of the base. Navy Medicine is further responsible for contingency healthcare operation, provided through several shipboard Fleet Surgical Teams, Fleet Hospital, and Medical Expeditionary Units. Navy Medicine also manages two Hospital Ships, USNS Mercy and USNS Comfort.

Among the various functions of BUMED, one of the most complex and important is in the area of resource management. Working through the Assistant Chief for Resource Management/Comptroller, BUMED formulates principles and policies, and prescribes procedures and systems which will exercise effective control over the financial operations of the BUMED claimancy. Furthermore, it justifies and ensures optimum use of resources for the efficient delivery of health care. It also develops and maintains an integrated fiduciary system that is both accurate and responsive to the Office of the CNO, Navy Comptroller, Office of the Secretary of Defense, Office of Management and Budget, and Congress.

Additionally, the Naval Medical Logistics Command (NAVMEDLOGCOM) is the central medical logistics point for the Navy. The primary mission of the NAVMEDLOGCOM is to provide and coordinate medical and dental materiel management and logistics support to the operating forces, U. S. Marine Corps, and shore

activities. They also cooperate with other Offices, Commands and Agencies and Medical Materiel and Logistical Support matters and to perform other related tasks as directed.[11]

Within NAVMEDLOGCOM there are several directorates to carry out this mission. One of those directorates is the Equipment Support Directorate. The Equipment Support Directorate ensures technical support and management of equipment programs having Navy-wide medical and dental applications. NAVMEDLOGCOM is also responsible for developing and managing medical and dental equipment specifications, repair parts, provisioning, and maintenance systems for fleet and shore facilities. NAVMEDLOGCOM equipment support office provides biomedical engineering technical support and assistance for all equipment procurement and related programs.[12]

[11] http://www-nmlc.med.navy.mil/gov_only/default.htm, 24 November 2004

[12] http://www-nmlc.med.navy.mil/gov_only/equipment/equipment.htm,, 24 Novemner 2004

III. HOW WE CAME TO THIS STUDY

A. INTRODUCTION

Every medical facility, worldwide, must account for and repair their medical equipment on a regularly-scheduled basis. The ability to locate equipment while conducting an inventory, or even, more importantly, trying to find a piece of equipment to repair or calibrate is always a challenge. Most of the equipment used on patients tends to be mobile, so the equipment moves between departments with ease, while maintaining no accountability. The ability to locate the equipment by either the biomedical repair technician or the equipment manager becomes a time-consuming task that doesn't always result in the location of the equipment that they are trying to find.

The healthcare facilities that exist within the DoD are no different from the healthcare facilities within the civilian sector when it comes to this issue. Within the Bureau of Medicine and Surgery (BUMED) system it is a requirement that an inventory be conducted within each medical facility to account for all medical equipment that exceeds $5,000 in value. In the case of equipment management, the inability to locate the equipment while conducting an inventory results in an unnecessary command investigation, as per the NAVMED P-5132 guidance.[13] These investigations can take anywhere from a week to several months, depending on the cost of the item and the information that is obtained during the information-gathering process. These investigations are not only time consuming, but they also use many man-hours when it comes to conducting the investigation by the investigating officer (E-7 or above) and review by the Commanding Officer (CO), O-6 or above. If the equipment is vital to the operation of the facility it must also be replaced, which is another unnecessary outlay of money.

Ask any healthcare professional what the most important aspect of any healthcare facility is, and they will all tell you his/her patient safety and maintaining the standard of care that patients have come to expect from our healthcare system. To provide this safety

[13] NAVMED P-5132

and standard of care, equipment must be repaired when down and preventive maintenance performed periodically to ensure that the piece of equipment is functioning properly before use on a patient. All too often when biomedical technicians go to find a piece of equipment that is due for maintenance or has been reported as inoperative, he/she can't find it because it has been moved from its assigned department. The NAVMED P-5132 provides guidance to the biomedical technician, telling him/her certain pieces of medical equipment, regardless of value, must be calibrated and maintained on a regular schedule based on its designated classification. Each classification determines how much time lapses before the equipment is brought into the repair shop for recalibration. Failure to perform the regularly scheduled maintenance and corrective maintenance on a certain piece of equipment jeopardizes our ability as medical professionals to provide safe and outstanding care.

B. ANECDOTES

I, LT Nixon, reported to Naval Hospital, Oak Harbor, in October 2001 as the Department Head of Material Management. Within my department I was in charge of six divisions, and of those six divisions two were directly related to equipment. The two divisions that I'm speaking of are Bio Medical Equipment repair, and the Equipment Management Division. Soon after taking over as the department head I went around to learn a little about each division. When I came to my biomedical equipment repair division I asked many questions about how they performed repairs, what dictated which repairs would be performed, and when. Once the biomedical equipment repair technician (BMET) and I started reviewing the records, it became obvious that several pieces of vital equipment that were used on patients daily had not been brought in for preventive maintenance or calibration.

Two of the main items that I noticed immediately and were of most concern to me for patient safety were the patient vital signs machines, since every patient has their vitals taken before seeing the doctor or nurse, and the many infusion pumps that we had throughout the hospital ward, clinics, and emergency room (ER). The infusion pump regulates the amount of intravenous fluid (IV) administered to the patient, as well as the

amount of medication that would be infused into the IV fluids. I told the BMET that I wanted him to go out and collect five pumps at a time, calibrate them, and then rotate them back into their appropriate areas, while keeping the equipment manager aware of where they were within the hospital. The BMET immediately ran a list of the infusion pumps that we had listed within the command and went out to collect them in groups of five.

Upon reaching the clinics, he would collect five and match them up with serial numbers assigned to them, to ensure that he had calibrated all of them. After calibrating all that he could find within the hospital, he still had ten machines that he couldn't find. I had him and the equipment manager, along with departmental personnel, out looking for the missing pumps, only to find them in broom closets, broken, due to mishandling. All in all it took over two and a half weeks of six hours on average a day looking for the missing pumps, time that should have been spent finishing the calibration on the pumps and starting on the vital signs machines. Once we started on the vital signs machines, the story was not that much different.

Another story of missing equipment had to do with that of a leased wound vacuum. This piece of equipment was under lease, but had gone missing for over four months; all the while we were paying for the lease. When the lease was up it was up to the medical facility to return the wound vacuum, but the facility still had not located the piece of equipment, therefore the facility had to not only pay the lease, but had to purchase the equipment as well.

Every three years BUMED requires that all Navy Medicine (NAVMED) Medical Treatment Facilities (MTF) conduct a triennial wall-to-wall inventory of all items accounted for in the property records. Additionally, a wall-to-wall inventory is also required whenever there is a change of command and a new CO takes over. When I first reported to my last hospital, it was obvious that a wall-to-wall inventory had not been completed in quite some time. The NAVMED P-5132 states that all equipment should be accounted for and made the responsibility of the department head in charge of the department in which the equipment is to be stored and used. When I reported onboard, this had not been done. Furthermore, there had not been an equipment manager doing the

job full time, as should have been the case. When my new Ships Serviceman (SH) Second Class reported in, I decided to make her the new equipment manager, a job in which she had had no previous experience. I sent her to the Defense Property Accounting System (DPAS) introductory class to learn our property accounting system and how we accounted for our property. My SH2 was also at another disadvantage in that she was not a Hospital Corpsman (HM), or medically trained in any way.

When SH2 returned we sat down and talked about what she had learned. It was now time for me to tell her that I needed her to complete a wall-to-wall inventory for the upcoming change of command. I put a note out to all department heads letting them know that SH2 would be coming around conducting a full inventory of their departments and that she would require one person who was medically trained to assist her in locating the equipment. SH2 ran a master list of all of the equipment that was within her system (which was not accurate) and she began her task of locating the equipment and accounting for a wall-to-wall inventory. She would spend her entire day going through departments trying to locate medical items with which she was totally unfamiliar, not knowing what function they performed. Many departments provided an HM to assist her in locating items since they were trained to know what most of these items were, but despite my request via e-mail, several others stated that they were too busy to provide anyone for assistance.

After two months of going through all of the clinics, wards, labor and delivery, emergency room, operating room, and support offices, SH2 had identified most of the items that were on the master list. She also added to the property records items that weren't being tracked and should have been. Despite her intense effort at finding everything, she still had items on the list that she was unable to locate. I notified the Commanding Officer (CO) of the situation, that not all pieces of equipment had been accounted for and that we were running against the clock with his impending change of command, as well as some of the problems that SH2 experienced with some of the department heads.

The CO then directed all department heads, via e-mail, to assist SH2 in locating the missing equipment ASAP. Once the department heads engaged, we found out that

much of the equipment was stuck in cleaning closets in a locker somewhere or that it had been disposed of improperly and that the equipment management division was not notified. By the time the wall-to-wall inventory was complete, we were missing several items for which a formal investigation was not required. There were two items, though, that necessitated a DD Form 200, Financial Liability Investigation of Property Loss, to be processed as prescribed in the NAVMED P-5132. An investigating officer was assigned to investigate the missing equipment. The investigating officer was an O-3 Nurse Corps, which meant that she spent two full days conducting interviews and preparing a recommendation for the CO, while putting her regular duties on hold. The recommendation was then forwarded up to the CO for review and approval or disapproval from departmental responsibility. This process took an additional day. When you look at all of the people involved in trying to locate the equipment, find out why it was missing, and deciding on the disposition of the matter, their respective pay grades, and the cost to replace it, the endeavor becomes very costly.

C. HOW WE SELECTED THE ITEMS IN OUR BASKET OF GOODS

When we initiated our study on this project, given our time constraint, we realized that it was unrealistic to research over 13,500 line items effectively that are managed by the PP&E manager at NMCSD. Since our main objective is to determine whether implementing RFID for equipment tracking is cost effective and realistic, we elected to pick a basket of goods, comprising six items, for our study. The next hurdle was to determine which specific items to select for our study. For item selection we called eXI Wireless Systems, Inc., the provider of Assetrack for hospital equipment management, due to their experience in this field and having performed studies and deployed RFID in the civilian healthcare system. From their experience and studies, they provided us with the following items that typical hospitals tend to have problems with: Infusion pumps, wheelchairs, stretchers, defibrillators, vital sign monitors, and ultrasound machines.[14]

[14] Phone conversation with Stacy Mountford, eXI Wireless Systems Inc., 30 September 2004.

When we performed our site visit, NMCSD stated that they were experiencing problems with the same assets identified by eXI wireless, but they were not interested at the moment in tracking wheelchairs and stretchers. NMCSD PP&E manager provided us with a list of six items that they felt would be beneficial to track using an RFID infrastructure. Three items identified by eXI Wireless Systems, Inc. as being problematic in civilian hospitals coincided with NMCSD's list. The items selected are the following:

- Blood analyzer
- Defibrillators
- Heart detector/monitor
- EKG
- Infusion pump
- Vital sign machine

There were several reasons why NMCSD and our team decided to select the listed items for our study. First, the items have a high daily usage rate, with the exception of the defibrillators. Second, the items are mobile and as such, they can easily end up moving to other departments and/or floors away from the inventoried location. Third, these items constantly require calibration and preventive maintenance, which means that biomedical repair personnel spent many man-hours searching for specific serial-numbered assets. Finally, these items pose a major health risk to patients if not properly calibrated/maintained, and as such, it is critical that the location of these assets be known at all times for timely maintenance.

A thorough comperative analysis of the items in our basket of goods to the remaining items is found in Chapter V section B(2).

IV. METHODOLOGY

A. INTERVIEWS

1. Companies Providing RFID Asset Tracking Solutions

To answer our question of what benefits, if at all, an RFID system would have on NMCSD to track assets, we decided to conduct interviews with the civilian sector first to answer our basic question of what benefits were attained at civilian hospitals. We also needed to understand the limitations of the current technology and what would be a realistic RFID infrastructure, given a limited budget. Our first phone interview was conducted with the Chief Operating Officer (COO) of Agility Healthcare Solutions, LLC, Mr. Dan Neuwirth. Agility Healthcare provides the RFID-enabled AgileTrac that will track, manage, and measure utilization of mobile assets. Mr. Neuwirth was very helpful and from the interview, we were able to understand how they typically operate and the potential benefits that an RFID infrastructure can offer. We also asked what type of items hospitals were tracking and what level of detail in location could an RFID tag provide. Of course, that answer was that it depends on what a hospital values and what it wants to track, and the detail also depends on how much money a hospital is willing to spend due to more readers needed to locate an asset within a few feet.

eXI Wireless Systems, Inc. which provides the Assetrac equipment locator system, has provided the team with countless examples of what they have seen from their studies in the civilian healthcare system. eXI has also been kind enough to offer their assistance regarding technical questions and have provided us with standard ROI calculations worksheets to measure the savings that can potentially be derived by hospitals.

2. Biomedical Engineering Personnel at NMCSD

When we interviewed senior enlisted biomedical personnel, their main concern was with the criticality of locating equipment requiring calibration/maintenance in a timely manner. Biomedical personnel see great potential in an RFID infrastructure to dramatically reduce the time it takes to locate equipment and as a consequence, more

time can be allocated on performing maintenance and calibration. As with all hospitals, NMCSD is concerned with patient safety. It is therefore critical that all equipment needing calibration or scheduled maintenance be accounted for at all times.

3. Plant, Property and Equipment (PP&E) Manager at NMCSD

Our interview with the PP& E manager at NMCSD, Mr. William Benson, resulted in insightful information. One of our goals was to find out from the property manager exactly how much money is spent replacing lost or stolen assets. Unfortunately, the databases he works with are unable to provide that level of detail. Additionally, when purchases for equipment are made, PP&E personnel do not know whether an item is being ordered due to the item being misplaced or stolen. Mr. Benson demonstrated the greatest interest in tracking equipment via an RFID infrastructure because he is the person that initiates inventories.

Mr. Benson also provided us with the total number of assets NMCSD manages, as well as the total number of items in our basket of study. When an item needs to be inventoried for any particular reason, a person is sent to look for the item in question and this task alone could take hours. When asked what he thought of having to access a web-based server to track equipment, he replied "that he was used to working with multiple systems for equipment accountability since NMCSD is mandated to keep DPAS and DMLSS for asset management."[15]

4. Comptroller at NMCSD

We decided to interview the Deputy Director of Resources/Deputy Comptroller at NMCSD to find out if expenditures were broken down by lines of accounting that would identify which expenditures were made to replace lost or stolen assets and how much money was spent for late fees on rented/leased equipment. Unfortunately, the database does not segment this information by lines of accounting. It is unfortunate because analysis on this data could be performed to see what percentage of a budget is being spent on lost assets and late fees.

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[15] Interview with Mr. William Benson, Plant Property and Equipment Manager, NMCSD, 8 October 2004.

B. PERSONNEL SURVEYED

An anonymous survey was created (see appendix A) and sent to twenty-five personnel, both biomedical equipment repair and medical equipment management personnel, ranging from E-4 through E-6. We chose the biomedical equipment repair and medical equipment management personnel because they are the personnel who must locate equipment on a daily basis to either perform maintenance (for the biomed personnel), or account for equipment (equipment management personnel). Out of the twenty-five personnel that we sent surveys to, we received a total of twenty-two responses, giving us a response rate of 88%.

We e-mailed the surveys to the personnel stated above and allowed a response period of two weeks. We discarded four of the surveys received because three respondents replied with a response of N/A for all of the questions that were presented. Out of the four, three discarded surveys were due to the fact that the personnel filling out the questionnaire were new to the position/job. The other survey was an outlier, which we decided to discard to prevent this nonreprestitive data from skewing our results. We sent out one reminder after the first week to remind the personnel being surveyed that they had one week left before we had to close out the survey.

We chose to administer a written survey so that we could remove some of the bias that exists in personal interviews and to tailor the questions more to the research that we were conducting. One of the problems that we found by conducting a written survey was that of interpretation. Each person could read a question and interpret that question differently, resulting in a wide range of responses that caused an outlier, such as the one mentioned above. Our survey included questions that required a written answer (questions 1 & 2) and question 3 through 9 were quantitative in nature.

Our survey was administered to find out information on the rank/pay grade of the person performing the work at hand, their position, amount of time spent trying to locate medical equipment (based on a basket of six pieces of equipment), and the assistance required in locating the equipment within other departments.

C. WHY NMCSD?

NMCSD is the largest military treatment facility in the world. It is comprised of 10 buildings, some with as many as six floors, totaling approximately 1,874,000 square feet, spread out on a compound that is located on an expansive area. As you can imagine, keeping track of anything in this vast facility would be a daunting task.

Conversations with medical staff in several clinics, units, and departments, it was concluded that the staff often found themselves without the equipment needed to monitor patients. Several clinics, units, or departments would have to chase down equipment that was moved out of their area with a patient to another floor and not returned, or equipment that was being used but wasn't listed as hospital property. Several staff members commented that hospital equipment gets moved around a lot and people lose track of where it is. Additionally, they felt that too much time and money was wasted looking for that equipment.

Out of all of the medical facilities within the Navy we chose NMCSD, not only because it was the largest, but because it also possesses medical equipment that would be found in any hospital facility, be it military or civilian, making it a good representation of a typical hospital. By using the data that we gain from NMCSD we will be able to apply our research to other facilities throughout the Navy, as well as DoD wide. Another reason that we decided upon NMCSD, as opposed to one of the other large Navy medical centers, such as Bethesda, or Portsmouth, was the proximity of the San Diego area to that of Monterey, California. Because of the fact that NMCSD was in close proximity and contained the necessary medical equipment to conduct our research, we determined that this was the ideal facility to obtain data to see if RFID would benefit or not benefit their facility.

In what ways is NMCSD typical and atypical within the Navy healthcare system? NMCSD, as stated earlier, is the largest military medical treatment facility, which means that it is different in many of its services, yet very similar to that of its smaller sister facilities, making it typical as compared to other facilities. A small hospital like Naval Hospital, Oak Harbor, Washington (25-bed hospital) provides services such as Internal Medicine, Physical Therapy, Labor and Delivery, Pharmacy, Laboratory, and others, but

they provide no acute care. If you look at NMCSD, they provide the same services that Naval Hospital, Oak Harbor does, but on a larger scale. These same services are basic throughout the Navy hospitals that are disbursed around the globe.

As medical facilities grow in size they provide more services to a broader patient base. For instance, Naval Hospital(s) Camp Pendleton, Bremerton, and Jacksonville are considered medium size hospitals and provide a greater scope of care than, say, the smaller hospitals like Oak Harbor, but not as great as NMCSD. NMCSD is designated as a major trauma center, a teaching hospital, and provides specialized care that is only found in a medical center setting, making it atypical when compared to our other facilities.

D. HOW WE ASSIGNED A DOLLAR VALUE TO ONE WORK HOUR

To answer our question regarding the financial viability of implementing RFID, we needed to assign a dollar value to a man-hour for the ROI analysis. We used the Medical Expense and Performance Reporting System (MEPRS) composite rate table to extract the average monthly pay of any given pay grade. MEPRS is used by medical DoD to keep statistical information, one being the average monthly pay of all pay grades in the military. The average monthly pay takes into consideration all pay, allowances, and benefits a military member receives, to include basic pay, housing allowance, commuted rations, medical, and dental. Since our survey respondents were E-4 to E-6 pay grades, we used the following average monthly pay data from MEPRS:

- E-4 $4,256.00
- E-5 $5,147.00
- E-6 $6,062.00

Since our 18 survey respondents consisted of six E-4s, nine E-5s, and three E-6s, we calculated a weighted average to come up with a monthly pay amount.

Pay grade	Respondents in paygrade	MEPRS Monthly pay	Total Monthly pay
E-4	6	$ 4,256.00	$ 25,536.00
E-5	9	$ 5,147.00	$ 46,323.00
E-6	3	$ 6,062.00	$ 18,186.00
Weighted average monthly pay			**$ 5,002.50**
Formula ($25,536+$46,323+$18,186)/18			

Table 1. Monthly pay weighted average calculation

Since we are calculating man-hours, we further divided the weighted average monthly salary to an hourly rate. MEPRS database uses 168 hours as a full work month, and therefore our hourly weighted average pay for our respondents at NMCSD equaled $29.78 ($5,002.50/168). As previously mentioned, the $29.78 hourly rate includes base pay, benefits, and allowances.

E. ESTABLISHING AN INFRASTRUCTURE COST BASELINE

To establish a cost baseline to work from, our team contacted eXI Wireless Systems, Inc., and used their Assetrac system as our model. eXI is a company that is located in Richmond, British Columbia, Canada. The company currently has existing systems installed in medical facilities within the US and Canada. eXI provided us with a rough financial cost estimate based on the square footage and a Real Time Locator System (RTLS). However, the authors and eXI representatives want to make it clear that the figures provided are an **estimate**. For an accurate quote a site visit would need to be conducted and actual floor plans analyzed. The rough estimates that were provided are as follows:

- Servers, Consoles, and Common Components $396,924.00
- Infrastructure Devices $503,948.00
- Installation and Training $354,266.63
- Total $1,255,138.63

At this cost, the estimate location of an asset could be pinpointed to within approximately 10 feet. We also estimated the cost of the active RFID tags to be about $27.70 for a quantity of 13,500.

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V. RESULTS AND DATA ANALYSIS

This portion focuses and reviews the responses to the Inventory Management/BioMedical Repair survey sent to Biomedical Equipment Repair and Property Management personnel at the NMCSD. This portion contains some analysis of survey data. The responses have been summarized and consolidated into Microsoft Excel worksheets and charts. The data is reviewed in the same order questions were presented in the survey.

As stated in Chapter IV, Methodology, Section B, Personnel Surveyed, our response rate was 88% (twenty-five sent, twenty-two received). Actual received surveys are found in Appendix B. Out of the twenty-two respondents, we had to eliminate four surveys. Respondents 6, 7, & 8 data was removed from our sample due to insufficient data provided on survey. Respondent 20 data was not included due to unrealistic responses (outlier).

A. SURVEY RESPONSE

Inventory Management/Biomedical Repair Questionnaire

1. What is your current Rate and Pay grade? (e.g., SH3/E4)

Pay Grade E-4	Rate	Pay Grade E-5	Rate	Pay Grade E-6	Rate	
1	SH	1	SH	1	HM	
1	SH	1	SH	1	HM	
1	SH	1	HM	1	HM	
1	HM	1	HM			
1	HM	1	HM			
1	HM	1	HM			
		1	HM			
		1	HM			
		1	HM			
6	**Total**	**9**	**Total**	**3**	**Total**	18 **Grand Total**
3	**SH**	**2**	**SH**			5 **SH**
3	**HM**	**7**	**HM**	**3**	**HM**	13 **HM**

Table 2. Survey responses to question 1

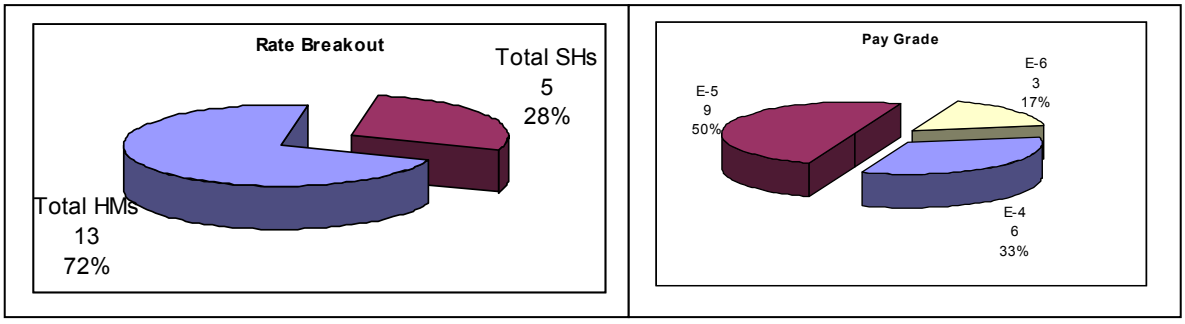


Figure 3. Respondents rate and pay grade breakout

2. What is your primary duty?

Primary Duty
Inputs
Disposal Computer and Med. Equipment
DLMSS/DPAS Manager
DMLSS/DPAS
Prop "D" Prop "A"
Repair Equip
Medical Repair Technician
Medical Repair
Biomed Tech
Team Leader of Team 2 (PM's Repair) Medical Equip Repair
Medical Repair
Medical Repair
Medical Repair
BMET
BMET
Basic BMET
BMET
Advanced BMET

Table 3. Survey responses to question 2

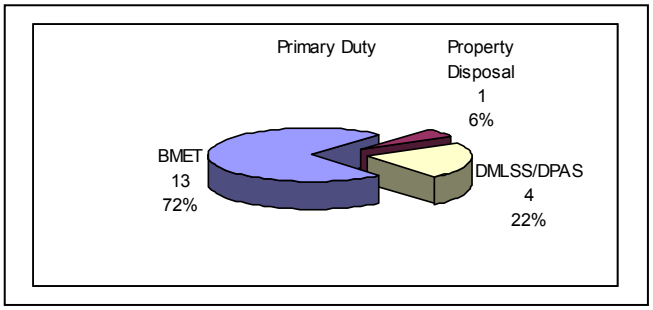


Figure 4. Primary duty of respondents

3. How long have you been performing your current duties? (Please answer in years and months.)

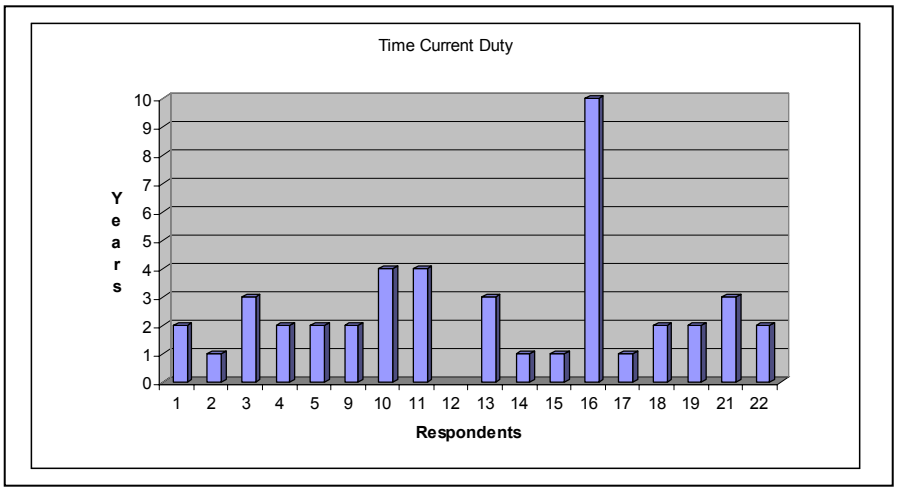


Figure 5. Survey responses to question 3

4. On average how much of your day is spent looking for equipment? (Please provide answer in hours and minutes.)

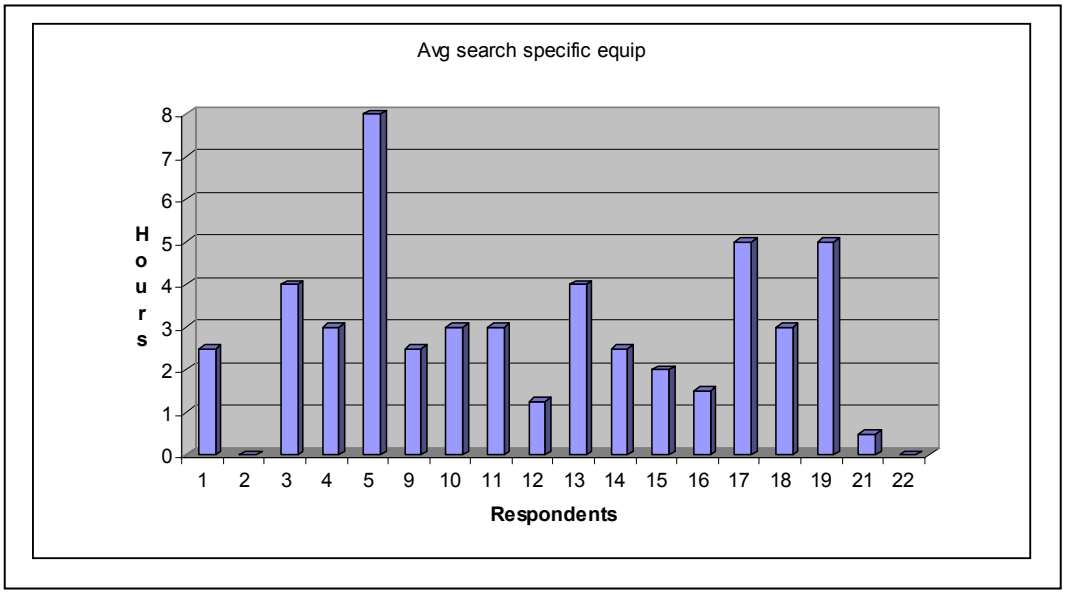
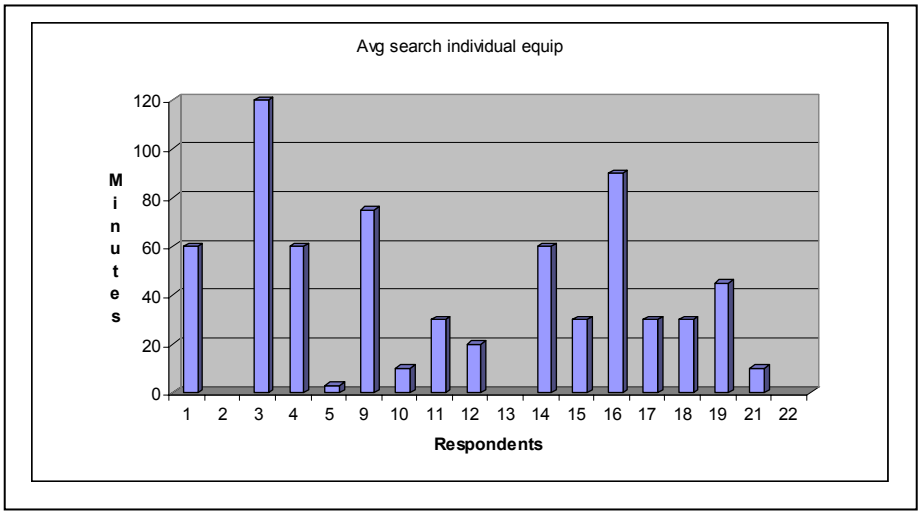


Figure 6. Survey responses to question 4

Avg time an individual spends searching for items daily	**3.2**	**Hours**
40%	**of 8 Hour Day on average is spent searching for Equipment**	
60%	**Spent of Primary Duty**	

Table 4. Analysis to survey question 4

5. On average how much time would you estimate that you spend searching for an **individual piece** of medical equipment? (Please provide answer in hours and minutes.)



Average search for Individual Equipment 44.87 Minutes

Figure 7. Survey responses to question 5

6. What is your best estimate for time spent looking for the following items (i.e. specific serial number)? (Please provide answer in hours and minutes.)

Blood Analyzer Minutes	Defibrillator Minutes	Heart Monitors Minutes	Infusion Pumps Hours	Electro Cardiograms (EKG) Minutes	Vital Signs Machine Hours
60	120	30	0.42	18	0.12
120	60	30	0.5	60	0.5
60	60	60	1	60	1
20	20	20	0.33	20	0.33
10	5	15	1	30	0.5
30	30	30	0.5	30	0.5
20	5	30	0.42	15	0.33
10	10	45	0.75	5	0.75
20	5	45	0.5	10	0.33
15	5	10	1	15	0.5
5	1	30	1	30	1
13.5	13.5	22	4.5	150	2.5
60	15	60	16	60	24
60	60	30	8	60	12
N/R	30	60	16	60	24
35.96 Minutes **Average time searching for Blood Analyzers**	**29.30 Minutes** **Average time searching for Defibrillators**	**34.47 Minutes** **Average time searching for Heart Monitors**	**3.46 Hours or 207.68 Minutes** **Average time searching for Infusion Pumps**	**41.53 Minutes** **Average time searching for Electro Cardiograms (EKGs)**	**4.56 Hours or 273.44 Minutes** **Average time searching for Vital Signs Machines**

Table 5. Survey responses to question 6

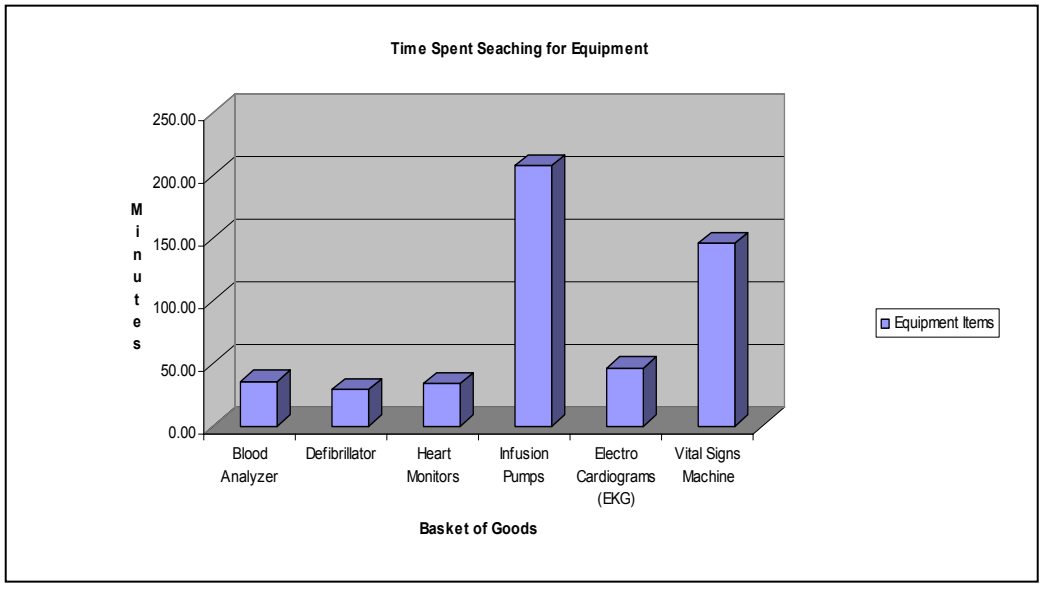


Figure 8. Minutes spent searching for equipment in our basket of goods

7. At what point do you feel that you've exhausted all of your resources in searching for an item listed above and decide to forward the issue up your chain of command? (Please answer in days and hours.)

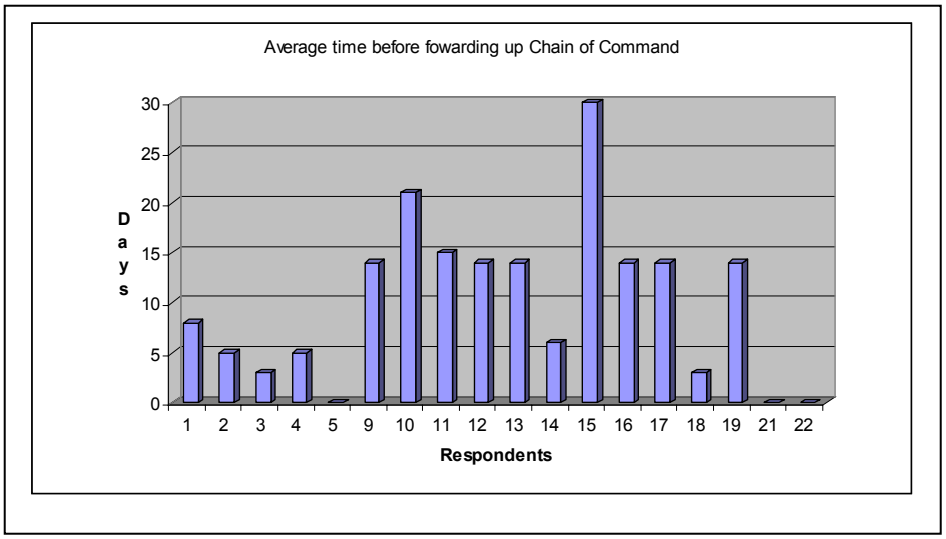


Figure 9. Survey responses to question 7

8. Rating the equipment from 1 to 5, 1 being unfamiliar, 5 being very familiar, how comfortable do you feel identifying different pieces of medical equipment when you enter a space?

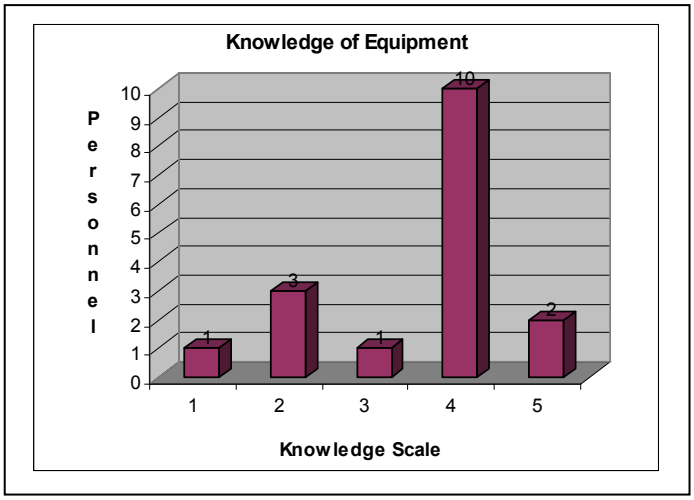


Figure 10. Survey responses to question 8

9. Using the scale below, how often do you require assistance from personnel within other departments?

% time require assistance in search for equipment				
0%	25%	50%	75%	100%
		1		
			1	
			1	
		1		
		1		
	1			
			1	
			1	
		1		
			1	
		1		
		1		
1				
				1
				1
				1
	1			
N/R				
1	**2**	**6**	**5**	**3**

Table 6. Survey responses to question 9

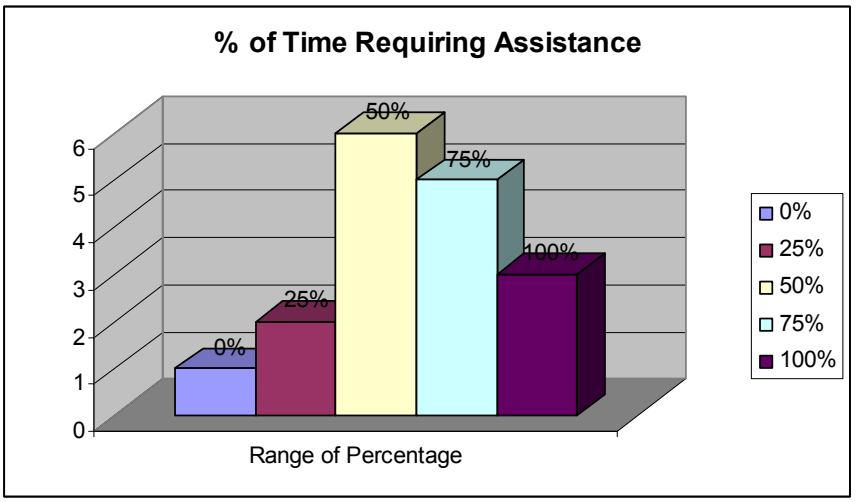


Figure 11. Frequency that respondent solicited personnel help from other departments

9a) On average, what is the typical pay grade of the individual assisting you?

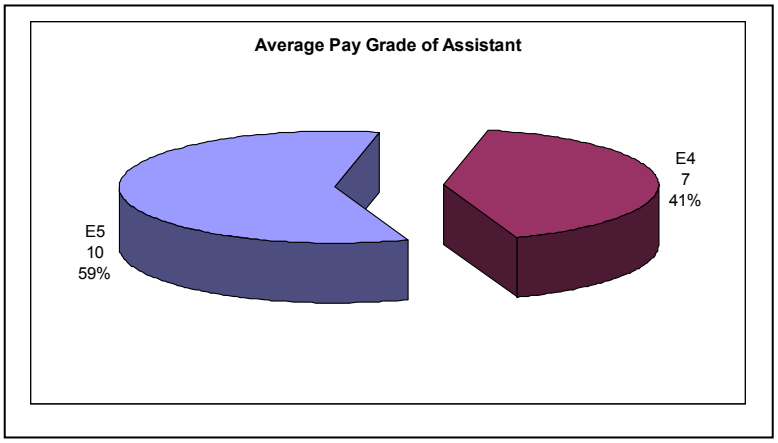


Figure 12. Survey responses to question 9a

B. STATISTICAL ANALYSIS

1. Time Analysis of Daily Man-Hours

For our research, we needed to calculate what percentage of a typical day biomedical and property management personnel utilize to solely search for equipment. From question four of our survey, respondents were asked to give the average time per day they spent searching for equipment. After compiling all the data, the result suggested that on average, the 18 respondents spent 3.2 hours of their day searching for equipment. When we divide the average hours by a typical eight-hour workday (3.2/8), our result yields 40%.

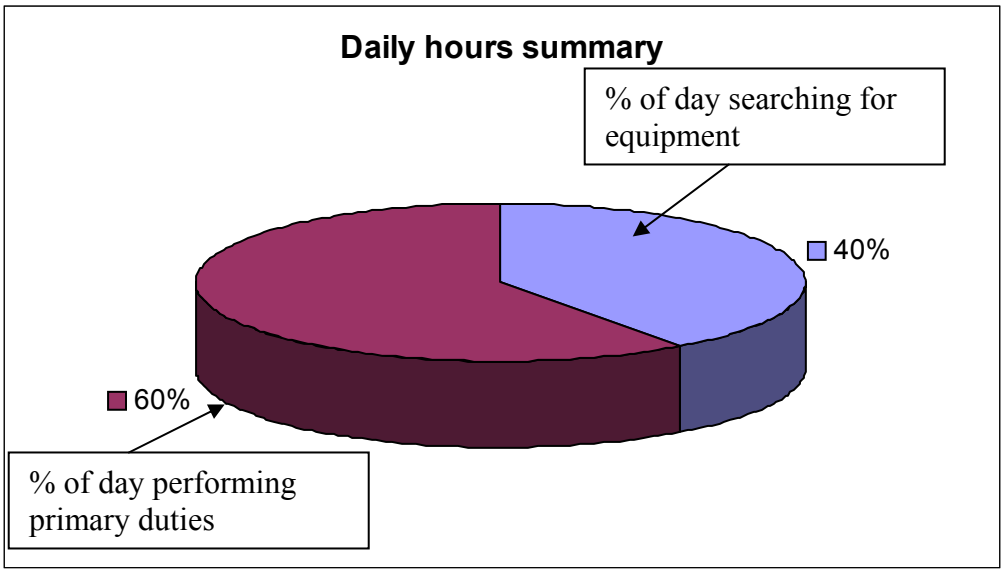


Figure 13. The average daily amount of time spent searching for equipment

2. Statistical Analysis of Basket of Goods

Most of the items in our basket of goods are mobile in nature due to the fact that the medical staff needs to be able to move the equipment to wherever it is needed to treat a patient. This could be in a treatment room, patient's room on the ward, in the middle of a hallway, or the emergency room. Nonetheless, there are some pieces of equipment that are not mobile in nature, and don't need to be tracked because they are stationary, therefore these items would not be represented by our basket of goods as selected. Examples of some equipment that isn't mobile are items such as Computed Tomography machine, treatment/OR tables, or dental chairs.

As we stated earlier, we chose a basket of six different pieces of medical equipment (which came to a total of 534 items, or 3.96% of total assets tracked at NMCSD) to study as our sample. To make this study valid we needed to choose goods that not only were misplaced frequently and/or lost, but we also needed to choose items that would be representative of the remaining 12,966 items tracked within NMCSD.

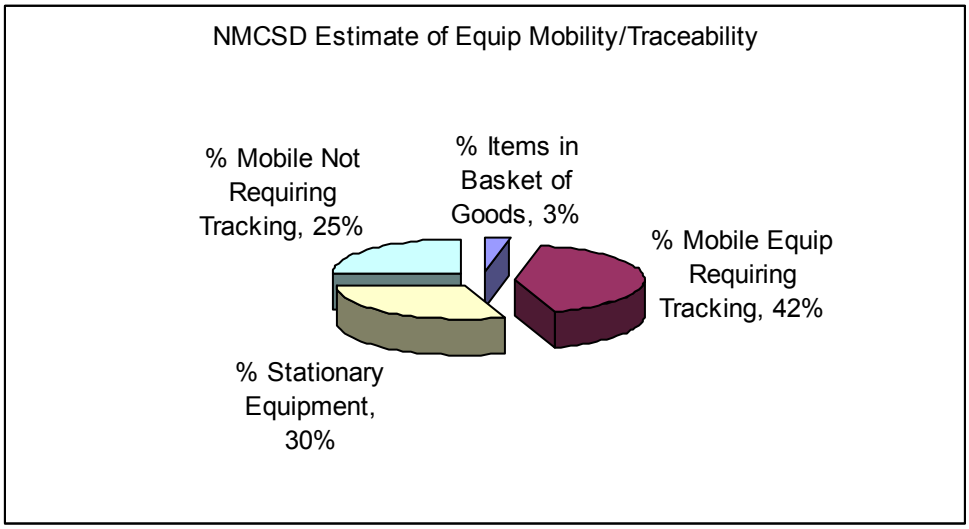

NMCSD Estimate of Equip Mobility/Traceability
% Mobile Not Requiring Tracking, 25%
% Items in Basket of Goods, 3%
% Mobile Equip Requiring Tracking, 42%
% Stationary Equipment, 30%

Figure 14. NMCSD's estimate of equipment mobility and traceability

The equipment items in our basket of goods are ideal to track with an RFID infrastructure because they are highly mobile, and require maintenance or calibration. Since not all equipment at NMCSD is mobile that requires maintenance or calibration, we needed to estimate what percentage of the total equipment tracked by NMCSD was similar to the items in our basket of goods. NMCSD provided us with estimates on approximately what percentage of items were stationary and items not requiring tracking, which would not make good candidates for tracking with RFID. Roughly 30% of items tracked by PP&E are stationary and another 25% do not require tracking.[16]

From the percentages provided by NMCSD, we created Table 8, that compares the items in our basket of goods to the remaining 12,966 items tracked through the DPAS database.

[16] Phone interview with HMC Santos Lopez, NMCSD property Management LCPO, 2 December 2004

Basket of Good comparison to Overall Medical Equipment Items		
	Basket of Goods	**Remaining Equip Items**
Number of Medical Equipment Items	534	12966
Total Medical Equipment Value	$ 3,045,052.10	$ 95,954,947.90
Average Cost of Medical Equipment	$15,494.64	$7,400.51
Average Search Time	82 Minutes	44 Minutes
% Items that are Moveable	100%	67%
Require Maintenance/ Calibration	100%	72%
Shrinkage	5%	5%

Table 8. Basket of goods comparison to remaining equipment items

In our basket of goods, we have a total of 534 items represented of the total 13,500 items tracked by NMCSD leaving 12,966 additional items. The average cost of an item in our basket of goods is double the average cost of the remaining items. Search time for items in our basket of goods is also double the time it takes to search for the remaining items. Based on question 5 from our survey in which respondents were asked to estimate how long it takes them to find a specific piece of equipment, we assumed that it takes, on average, 44 minutes to search for items not in our basket of goods.

We also assumed that 72% of the remaining items need periodical maintenance/calibration. Since an estimated 25% of items do not need tracking, we assumed that the remaining 75% needed to be tracked for calibration and maintenance purposes. Since our basket of goods is 3% of total assets, that leaves an estimated 72% or 9,336 items.

We also assumed that 67% of the remaining items were mobile based on the information provided by NMCSD where they estimate that 30% of the items are stationary. Since our basket of goods is comprised of 3%, that leaves an additional 67% (8,687) items that are mobile.

To estimate what percentage of the total assets are similar to the items in our basket of goods in that they are mobile and need periodic maintenance/calibration, we

eliminated 30% of items identified as being stationary, and 25% of items not requiring tracking. Removing the aforementioned percentages from the total remaining equipment count, we estimated that 42% (5,446) of the remaining 12,966 items are similar in nature to the items in our basket of goods. Based on our assumptions and analysis, we conclude that the 5,446 items plus the 534 items in our basket of goods are ideal for tracking with an RFID infrastructure.

Item	Class	Class PM Calibration Frequency	Quantity in Inventory	Total Annual PM/Cal	Average Time to find equip in minutes	Avgerage Weighted Hourly Wage	Cost of Item Search	Total Annual Search Cost
Blood Analyzer	III	Yearly	9	9	35.96	$ 29.78	$ 17.85	$ 160.63
Defibrillator	I	Quarterly	119	476	29.3	$ 29.78	$ 14.54	$ 6,922.26
Heart Monitors	II	Semi-Annual	57	114	34.47	$ 29.78	$ 17.11	$ 1,950.38
Infusion Pumps	III	Yearly	234	234	207.68	$ 29.78	$ 103.08	$ 24,120.37
Electro Cardiograms (EKG)	II	Semi-Annual	12	24	41.53	$ 29.78	$ 20.61	$ 494.71
Vital Sign Machines	II	Semi-Annual	103	206	145.44	$ 29.78	$ 72.19	$ 14,870.46
Totals			534	1063				$ 48,518.82
Average					82.40		$ 40.90	

Table 9. Annual cost expended searching for items in our basket of goods

The table above is a representation of the basket of goods we selected from NMCSD. Analysis of the above table demonstrates the Preventive Maintenance/Calibration (PM/CAL) Class Types for each item. Represented are the actual items in inventory at NMCSD provided from DPAS reports. Additionally, based on the Class Type Frequency, the total PM/CAL is determined for each group of items in the basket of goods.

The data in the table was summarized from responses to question six of the Inventory Management/BioMedical Repair Survey. Of interest is the "Average time to find Equipment" Column. The average time to find an item in our basket of goods is 82.40 minutes. Per the responses, the two items that take the longest amount of time to search for are Infusion Pumps and Vital Signs Machines. These items also happen to be the items with the largest quantity in our basket of goods.

Based on the weighted average hourly salary and the average time in minutes it takes to locate items in our basket of goods, we can compute the search cost of each

individual item, as presented in the table above. This is determined by taking the weighted average hourly salary and multiplying by the amount of time it takes for a search of an item divided by 60, e.g., for an Infusion Pump the cost per search is calculated as follows: $29.78 * (207.68/60) = $103.08. In other words, it takes on average $103.08 in man-hours costs to search for a specific Infusion pump. As depicted in our table, Infusion Pumps and Vital Signs Machines searches cost the most.

Taking this a step further to determine annual cost of searches for a particular category of items, we take the total amount of times an item is PM/CAL and multiply it by the cost of an item search, e.g., Heart Monitors are PM/CAL on a semi-annual basis at a cost of $17.11 per search. There are a total of 57 Heart Monitors, resulting in 114 annual searches, which yield a total annual cost of $1,950. This is assuming that PM/CALs are accomplished as required per Class Type on schedule.

Per Table 9, we can infer that if PM/CAL occurs on schedule per Class Type, and based on survey responses, the overall annual manpower cost of the searches for the items in our basket of goods will be approximately $48,518.

	# of items	Equipment value	Calculated annual search cost	Percentage of search cost to equipment value
Basket of goods	534	$ 3,045,052.00	$ 48,519.00	1.59%
Similar items	5445	$ 40,301,078.00	$ 642,146.00	1.59%
Total	5980	$ 43,346,130.00	$ 690,665.00	

Table 10. Cost comparison of items in basket of goods to similar items

Further analysis of the data, per NMCSD DPAS reports, the entire value of our basket of goods is $3,045,052. Per the survey results the annual cost to search for items in the basket of goods is $48,519, which represents 1.59% of the entire value of the basket of goods. Applying the 1.59% value to the remaining 5,445 similar items in inventory, which is valued at $40,301,078, we can deduce that annually it would cost approximately $642,146 to search for these remaining items.

C. RETURN ON INVESTMENT ANALYSIS

1. Introduction

The value of tracking medical assets throughout a facility goes beyond equipment and man-hour costs savings, it goes to the heart of our medical business, which is patient care and safety. Our ability to locate the equipment, calibrate, and perform preventive maintenance enhances our patient safety factor that will continue to provide and exceed our standard of care, as well as help us to conform to Joint Commission on Accreditation of Healthcare Organizations (JCAHO) standards.

The use of RFID in the military healthcare system is quite different from using it in the consumer packaged goods or electronics industries. Healthcare is a highly regulated industry. Furthermore, patient safety issues play a critical role in decision making. If a case of paper towels is sent to the wrong distribution center, warehouse, or store, another case can be easily ordered to replace it along the supply chain. However, if a crucial piece of medical equipment cannot be located for a critical medical procedure or for proper calibration or maintenance, it could prove to have devastating, dangerous, and potentially disastrous results for a patient's well-being.

How can the military healthcare system, specifically NMCSD, measure a true ROI of implementing an RFID system to track and manage medical equipment? NMCSD will not be the only organization facing this dilemma. There continues to be a great deal of debate and discussion about what exactly is the best cost-benefit analysis or business case for deploying RFID in several of the other industries. The technology has become more widespread in recent years and the cost of the technology has come down significantly over the years. An RFID passive tag currently costs approximately 25 cents each, and that cost is expected to decrease further during the next several years. Additionally, RFID frequency standards continue to become better established, which will enable even a broader base of users.

With RFID tag prices ranging from 25 cents and up for a simple license plate UHF tag, it's a challenge to find a truly favorable (dollar-wise) return on investment in

many industries. MTF commanding officers, military healthcare system officials and healthcare providers face the reality daily of ever shrinking resources and doing more with less. With salaries being one of the largest expenses in any organization, reductions in personnel are inevitable. From the rising cost of necessary medical supplies and ever-tightening budgets, this creates an almost impossible and increasingly difficult task.

Many of the assets used in the healthcare industry are expensive. It's obvious that if hospitals can improve the utilization of a $3,000 defibrillator or an EKG monitor, they can achieve a healthy ROI. Nonetheless, a majority of the inefficiencies can be found in the micro level, which is equipment below a value of $500 (i.e., wheel chairs). Analysis of items with a value below $5000 would be more difficult since these items are not tracked in inventory at NMCSD. However, by tagging items at this value, it could help improve the actual individual healthcare provider's regulatory compliance, patient safety, efficiency, and cost savings.

Furthermore, when we calculated our ROI analysis, we did not take into consideration the amount of time that is spent by HM's and nurses searching for equipment when they have to utilize assets on the spot for patients. With the RFID infrastructure, HM's, nurses, and doctors would have access to the web based equipment locator system from any computer or hand held device connected to the web. It is clear that the current method of tracking and inventorying equipment through the use of bar code is cumbersome, problematic and leads to inefficiencies.

2. What We Used for Our ROI Analysis

To analyze the ROI of implementing an RFID infrastructure, we used the figures provided by eXI Wireless, survey data, MEPRS monthly salaries and industry averages. We ran our model for a total of six years to see at what point the capital expenditure would be recuperated. We also ran our ROI analysis model using several assumptions (sensitivity analysis) changing variables of benefits and costs to find out the resulting Net Present Value (NPV). In our ROI model, we kept man-hours spent per day searching for equipment constant at 40%. We derived the yearly dollar amount using the following formula:

Computed monthly weighted avg salary	number of respondents	months	Total weighted annual salary	% of time searching for equipment	Annual cost of serching for assets
$5,002.50	18	12	$1,080,540.00	0.4	$432,216.00

Table 11. Annual cost of man-hours spent searching for equipment

3. Baseline ROI Analysis Assumptions

Our first ROI analysis model is used as the baseline. In the baseline model, we assumed that NMCSD equipment shrinkage or capital expenditures total 5% of the overall equipment value tracked by the PP&E manager due to the misplacement of assets or stolen equipment. Year one total equipment value of approximately $99,000,000 is what NMCSD currently has in their property records. For the following years we added 4% to the previous year's value to account for inflation, replacement and new requirements. Shrinkage will therefore remain constant at 5% for the following years, but the money value should increase due to a higher equipment inventory value. Our baseline model also assumes the tag in year one to cost $25.70, and we kept the cost constant for the following years to be conservative when the price should, in actuality, decrease over time. Additionally, for the following years, we assumed that NMCSD would require an additional 4% of new active tags to affix on newly-acquired equipment. For the infrastructure costs we received an estimate from eXI Wireless. Once again, this is only an **estimate**. An accurate quote necessitates an on-site visit by eXI Wireless to survey the hospital and have access to actual floor plans. For our baseline model, we assumed that 13,500 active tags would need to be purchased and the level of coverage obtained would be within 10 feet for the price. To capture the NPV of cash outflows and benefits for years two through six, we used the cost of money of 4.5%, which is the current 10-year U.S. Treasury rate.

a. Baseline ROI Analysis

Base Model	YR1	YR2	YR3	YR4	YR5	YR6
5%	$ 99,000,000	$ 102,960,000	$ 107,078,400	$ 111,361,536	$ 115,815,997	$ 120,448,637
13,500						
$ 25.70						
BENEFITS						
Shrinkage	$ 4,950,000	$ 5,148,000	$ 5,353,920	$ 5,568,077	$ 5,790,800	$ 6,022,432
Manpower cost	$ 432,216	$ 447,344	$ 463,001	$ 479,206	$ 495,978	$ 513,337
COST						
Install	$ (404,267)	$ -	$ -	$ -	$ -	$ -
Tags	$ (346,950)	$ (13,878)	$ (13,878)	$ (13,878)	$ (13,878)	$ (13,878)
Receivers & transmitters	$ (503,948)					
Maintenance	$ -	$ (30,000)	$ (30,000)	$ (30,000)	$ (30,000)	$ (30,000)
Net cashflow	$ 4,127,051	$ 5,551,466	$ 5,773,043	$ 6,003,404	$ 6,242,900	$ 6,491,891
NPV	$30,431,248.11					

Table 12. ROI analysis of baseline model

As our base model indicates, the first year has the highest cash outflow to create the RFID infrastructure, and our data shows that overall benefits outweigh the cost. In other words, the cost to create the infrastructure pays for itself the first year in the benefits attained from avoiding the 5% shrinkage and manpower cost savings associated with searching for equipment. Granted that manpower is considered a fixed cost, but the unproductive time being wasted searching for equipment could now be used by personnel to perform their primary assigned duties. From our ROI base model, NMCSD could save approximately $30,431,248 over a six-year period by installing an RFID system to track and manage medical equipment.

b. Assumption #1 ROI Analysis Based on a 10% Shrinkage-Rate

Assumption #1	YR1	YR2	YR3	YR4	YR5	YR6
10%	$ 99,000,000	$ 102,960,000	$ 107,078,400	$ 111,361,536	$ 115,815,997	$ 120,448,637
13,500						
$ 25.70						
BENEFITS						
Shrinkage	$ 9,900,000	$ 10,296,000	$ 10,707,840	$ 11,136,154	$ 11,581,600	$ 12,044,864
Manpower cost	$ 432,216	$ 447,344	$ 463,001	$ 479,206	$ 495,978	$ 513,337
COST						
Install	$ (404,267)	$ -	$ -	$ -	$ -	$ -
Tags	$ (346,950)	$ (13,878)	$ (13,878)	$ (13,878)	$ (13,878)	$ (13,878)
Receivers & transmitters	$ (503,948)					
Maintenance	$ -	$ (30,000)	$ (30,000)	$ (30,000)	$ (30,000)	$ (30,000)
Net cash flow	$ 9,077,051	$ 10,699,466	$ 11,126,963	$ 11,571,481	$ 12,033,700	$ 12,514,323
NPV	$59,778,243.27					

Table 13. ROI analysis assuming a 10% shrinkage rate

In our second ROI analysis, we assumed that NMCSD had the industry average of shrinkage, which is 10% of total equipment value in inventory, and left all other variables the same as our base model. In this ROI analysis, NMCSD would have to replace $9,900,000 worth of equipment. Additionally, by changing the 5% shrinkage rate to 10%, our ROI analysis shows that NPV savings over the same six-year period would amount to approximately $59,778,243, an increase of approximately 96.44% over our base model. This vast difference in savings tells us that the shrinkage rate used in our ROI analysis model is very sensitive and is where savings are gained by implementing RFID.

c. Assumption #2 ROI Analysis Based on a 50% Increase In Tags and Readers

Assumption #2	YR1	YR2	YR3	YR4	YR5	YR6
5%	$ 99,000,000	$ 102,960,000	$ 107,078,400	$ 111,361,536	$ 115,815,997	$ 120,448,637
13,500						
$ 38.55						
BENEFITS						
Shrinkage	$ 4,950,000	$ 5,148,000	$ 5,353,920	$ 5,568,077	$ 5,790,800	$ 6,022,432
Manpower cost	$ 432,216	$ 447,344	$ 463,001	$ 479,206	$ 495,978	$ 513,337
COST						
Install	$ (404,267)	$ -	$ -	$ -	$ -	$ -
Tags	$ (520,425)	$ (20,817)	$ (20,817)	$ (20,817)	$ (20,817)	$ (20,817)
Receivers & transmitters	$ (755,922)					
Maintenance	$ -	$ (30,000)	$ (30,000)	$ (30,000)	$ (30,000)	$ (30,000)
Net cash flow	$ 3,701,602	$ 5,544,527	$ 5,766,104	$ 5,996,465	$ 6,235,961	$ 6,484,952
NPV	$29,975,337.06					

Table 14. ROI analysis assuming a 50% increase in tag and receiver transmitter costs

In this model, we assumed that the costs provided to us for our baseline model were too conservative, and therefore we increased the cost of RFID active tags and receivers/transmitters by 50%. As our analysis indicates, even with an increase of 50% in the two variables aforementioned, and leaving all other variables equal to the baseline model, we still see a positive cash flow the first year of $3,701,602, and an overall NPV savings of $29,975,337, which tell us that the cost of tags and readers do not affect our overall savings as much as shrinkage.

d. Assumption #3 ROI Analysis Based on a 50% Decrease in Tags and Readers

Assumption #3	YR1	YR2	YR3	YR4	YR5	YR6
5%	$ 99,000,000	$ 102,960,000	$ 107,078,400	$ 111,361,536	$ 115,815,997	$ 120,448,637
13,500						
$ 12.85						
BENEFITS						
Shrinkage	$ 4,950,000	$ 5,148,000	$ 5,353,920	$ 5,568,077	$ 5,790,800	$ 6,022,432
Manpower cost	$ 432,216	$ 447,344	$ 463,001	$ 479,206	$ 495,978	$ 513,337
COST						
Install	$ (404,267)	$ -	$ -	$ -	$ -	$ -
Tags	$ (173,475)	$ (6,939)	$ (6,939)	$ (6,939)	$ (6,939)	$ (6,939)
Receivers & transmitters	$ (251,974)					
Maintenance	$ -	$ (30,000)	$ (30,000)	$ (30,000)	$ (30,000)	$ (30,000)
Net cash flow	$ 4,552,500	$ 5,558,405	$ 5,779,982	$ 6,010,343	$ 6,249,839	$ 6,498,830
NPV	$30,887,159.16					

Table 15. ROI analysis assuming a 50% decrease in tag and receiver transmitter costs

In our final ROI analysis we assumed a decrease in the price of tags and readers by 50% and left all other variables the same as in our baseline model. In this analysis, NMCSD would increase their positive net cash flow by $425,449 to $4,552,500, and overall NPV savings over the six-year period would be $30,887,159. As with our previous analysis of increasing cost by 50% of selected items, a decrease does not have a major impact on overall NPV over six years.

4. Payback Period Analysis

Since our ROI analysis showed a payback period of one year on our capital investment, we have performed an analysis to figure out how long it would take to recuperate our investment in months. To estimate cashflows for the first year, we made several assumptions using our ROI results. First, we assumed that the contractor was paid in full the first month of the contract. We also assumed that infrastructure implementation took four months and hence, there were no cashflows for months two through four. Once the RFID system is in place the 5th month, shrinkage and man-hour savings will begin to be realized. For monthly shrinkage savings, we took the first year's savings from our various ROI analyses and divided it by 12 (i.e., $4,950,000/12 = $412,500). For monthly man-hours saved, we took the annual cost of searching for equipment from our weighted average salary calculation and divided that amount by 12 (i.e., $432,216/12 = $36,018). Using the aforementioned assumptions, the following

payback tables were created for each of our ROI analyses providing a payback period in months.

Base Scenario	1st Month	2nd Month	3rd Month	4th Month	5th Month	6th Month	7th Month	8th Month
Investment	$ (1,255,165)	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Shrinkage saved	$ -	$ -	$ -	$ -	$ 412,500	$ 412,500	$ 412,500	$ 412,500
Labor savings	$ -	$ -	$ -	$ -	$ 36,018	$ 36,018	$ 36,018	$ 36,018
Cash Flows	$ (1,255,165)	$ -	$ -	$ -	$ 448,518	$ 448,518	$ 448,518	$ 448,518
Payback	$ (1,255,165)	$ (1,255,165)	$ (1,255,165)	$ (1,255,165)	$ (806,647)	$ (358,129)	$ 90,389	$ 538,907

Table 16. Baseline scenario payback period

In the baseline scenario and using our assumptions, the project would realize a positive payback in the seventh month with a net gain of $90,389.

Assumption #1	1st Month	2nd Month	3rd Month	4th Month	5th Month	6th Month	7th Month	8th Month
Investment	$ (1,255,165)	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Shrinkage saved	$ -	$ -	$ -	$ -	$ 825,000	$ 825,000	$ 825,000	$ 825,000
Labor savings	$ -	$ -	$ -	$ -	$ 36,018	$ 36,018	$ 36,018	$ 36,018
Cash Flows	$ (1,255,165)	$ -	$ -	$ -	$ 861,018	$ 861,018	$ 861,018	$ 861,018
Payback	$ (1,255,165)	$ (1,255,165)	$ (1,255,165)	$ (1,255,165)	$ (394,147)	$ 466,871	$ 1,327,889	$ 2,188,907

Table 17. Assumption #1 scenario payback period

In our first assumption where we assumed that NMCSD's shrinkage rate was equal to the industry's average of 10%, our calculation shows that the initial investment is recouped by the sixth month.

Assumption #2	1st Month	2nd Month	3rd Month	4th Month	5th Month	6th Month	7th Month	8th Month
Investment	$ (1,680,614)	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Shrinkage saved	$ -	$ -	$ -	$ -	$ 412,500	$ 412,500	$ 412,500	$ 412,500
Labor savings	$ -	$ -	$ -	$ -	$ 36,018	$ 36,018	$ 36,018	$ 36,018
Cash Flows	$ (1,680,614)	$ -	$ -	$ -	$ 448,518	$ 448,518	$ 448,518	$ 448,518
Payback	$ (1,680,614)	$ (1,680,614)	$ (1,680,614)	$ (1,680,614)	$ (1,232,096)	$ (783,578)	$ (335,060)	$ 113,458

Table 18. Assumption #2 scenario payback period

Our second assumption in which we assumed an increase of 50% for the cost of RFID active tags and receivers/transmitters, we begin to see a positive cashflow in the eight month.

Assumption #3	1st Month	2nd Month	3rd Month	4th Month	5th Month	6th Month	7th Month	8th Month
Investment	$ (829,716)	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Shrinkage saved	$ -	$ -	$ -		$ 412,500	$ 412,500	$ 412,500	$ 412,500
Labor savings	$ -	$ -	$ -		$ 36,018	$ 36,018	$ 36,018	$ 36,018
Cash Flows	$ (829,716)	$ -	$ -	$ -	$ 448,518	$ 448,518	$ 448,518	$ 448,518
Payback	$ (829,716)	$ (829,716)	$ (829,716)	$ (829,716)	$ (381,198)	$ 67,320	$ 515,838	$ 964,356

Table 19. Assumption #3 scenario payback period

Our third assumption in which we assumed that the RFID tags and readers/transmitters were 50% cheaper. Our table shows that the project has a positive return the sixth month, same as assumption #1, but with a smaller dollar value.

As with our ROI analysis, our payback period calculations showed a positive cashflow within a few months after the RFID system implementation mainly due to the savings realized in equipment shrinkage.

5. Our Assumptions about Shrinkage

Our ROI analyses show a substantial amount of dollars saved in year 1 based on the amount of savings from shrinkage alone. It is for this reason that we take a closer look at shrinkage and what it means and how RFID can possibly mitigate this problem.

Webster's Dictionary defines the term "shrinkage" as the act of shrinking. Within the logistics community when inventory of equipment or supplies becomes smaller due to loss, theft, obsolescence, or breakage we refer to the decrease in quantity as shrinkage. For our project we will treat shrinkage as lost or stolen equipment. The reason that we have decided to concentrate on these two aspects of shrinkage is due to the fact that these are areas that can be controlled through better tracking and accountability. As we looked at the obsolescence and breakage portions we came to the conclusion that these two areas are somewhat uncontrollable, at least through tracking. By this we mean that obsolescence is something that occurs due to advances in technology or other forces outside of our control, whereas breakage occurs due to accidents, which can be controlled through attention to detail but not through a tracking mechanism.

Why did we use a 5% shrinkage rate to calculate or baseline ROI? eXI Wireless Systems Inc. is a provider of asset tracking solutions using RFID and they have performed numerous studies along with RFID installations at civilian healthcare facilities. eXI estimates that the average rate of shrinkage that occurs within a hospital due to lost, misplaced or "hoarded" equipment is between 5% - 15 % per year.[17] Bon Secours is a medical group in Maryland that owns 17 different hospitals within the

[17] eXI Wireless Systems, Inc., Assetrac ROI Brochure

Maryland and Virginia area. Agility Healthcare, another company in the medical equipment tracking business through RFID, conducted a study of the Bon Secours healthcare system and found that they were losing 10% of their inventory annually on average.[18] The 10% loss in inventory that Agility estimated corroborates the industry 5% - 15% estimate referenced above from eXI.

We estimated the NMCSD shrinkage rate to be at approximately 5%. Our reasoning for choosing a figure less than the estimates of our civilian counterparts is due to the fact that access to the NMCSD grounds is controlled by a military gate guard and requires a government identification card for entrance.

Due to the fact that shrinkage is estimated to provide the highest ROI, it is our recommendation that a thorough analysis using actual property records be conducted to estimate the actual amount of shrinkage in a year. The question is how can NMCSD accurately determine a shrinkage percentage? One way of collecting data on shrinkage due to loss or theft would be to look at NMCSD's DD Form 200, Financial Investigation of Property Loss on file. The DD Form 200 is used whenever an item is tracked within DPAS and is either lost, or stolen. The responsible department head is responsible also to initiate this form to report an item as lost or stolen. The CO is notified and initiates an investigation that is performed by an officer independent of the department in question to find out the background concerning the missing item. When the investigating officer has reported his findings and completes the required report, it is returned to the CO for final disposition. The problem with trying to account for shrinkage via DD Form 200 is that it's only required for DPAS-tracked items (items above $5000) and does not include items that might not be tracked, yet still disappear from the hospital.

Additionally, there are numerous times where missing items go unreported and are usually identified as missing during a required inventory. For these reasons, gathering data solely from the DD Forms 200 will provide only a portion of shrinkage but will not be the most effective tool to accurately determine actual overall shrinkage.

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[18] Casey, Michael, "New Technology Focuses on Equipment Management", The MC Report, 8 June, 2004

Since another assumption of shrinkage is due to theft by either hospital employees or patients, there needs to be a mechanism to capture data on stolen medical equipment. RFID has been a buzzword within the logistics field these days, from cross docking, to inventory management. Total asset visibility is another aspect in which RFID has been utilized to better improve equipment tracking while reducing losses and theft. As RFID technology continues to rapidly mature, we feel that RIFD systems will be able to minimize the amount of theft. An RFID infrastructure can be set-up in many ways, depending on how far the facility wants to track equipment. For instance, readers can be placed at the perimeter of the compound to identify medical equipment leaving the area. As these readers identify equipment leaving the compound they will alert the hospitals security force. Beyond the alarms, the fact that the staff will be aware of equipment tracking through RFID for accountability and theft can serve as a deterrent that will force the staff to think twice before trying to obtain a piece of equipment illegally for possible personal use. Thefts committed by patients however will be left up to the alarm system as a deterrent. For those people who think that they can bypass the system by removing the RFID tags so that they won't be caught, eXI Wireless tags and possibly other providers, offer tamper proof active tags that cannot be shielded from a transponder.

Another piece of the shrinkage puzzle is when hospitals order equipment for items that cannot be found within the hospital itself for various reason. By tagging equipment throughout a hospital with an active RFID tag, each piece of equipment is tracked as it moves within the different wings and floors of the hospital. By using this technology, no longer will equipment be placed in a closet and be forgotten because as the equipment is placed into the closet, the computer server is automatically updated, virtually eliminating the possibility of lost equipment. Furthermore, any medical staff member with web access to the locator system can log in and see exactly where a specific item is located. No longer will there be unnecessary expenditures for misplaced/lost equipment since the location of all items tagged with an active RFID tag will be known at all times.

RFID has made great strides in recent years throughout the supply chain management pipeline, and as pointed out above the medical equipment field is one the fields that have gained from these advances. From conducting our research for this

project, we have noticed that there is a major trend in the civilian healthcare community to implement RFID technology not only for asset tracking, but for process improvements as well. We also see this as a trend because there are countless firms that have recently begun to offer asset-tracking solutions to hospitals through RFID. As such, many of our civilian healthcare counterparts have already realized the benefits and cost savings that can be realized by implementing such technology within their facilities.

The DoD has realized that this technology has many applications throughout many of the different divisions of the different services, mandating the use of RFID in some areas. As this technology is proven in the civilian healthcare sector and more people see how it can benefit the military healthcare field as well, RFID will be deployed to track equipment, medical supply inventories, patients, records, and more. As stated above our civilian counterparts, some being for profit facilities, have already realized the benefit of reducing costs and increasing profit through equipment tracking alone. Even though the military facilities are a not for profit entities, we can still reap the benefits of lowering the cost of replacing equipment that has either been misplaced, or stolen, as well as decreasing the amount of search time realizing cost savings in man-hours.

Additionally, RFID equipment tracking will increase patient safety by locating equipment for proper calibration and preventive maintenance. NMCSD has already realized what benefits can be gained from RFID and has already submitted a procurement package to the NAVMEDLOGCOM, if this package is approved NMCSD could quite possibly be the pioneering force to bring this beneficial technology into the DoD healthcare arena.

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VI. OTHER POTENTIAL USES OF RFID WITHIN A MTF

A. PATIENT MEDICAL RECORDS TRACKING

A big problem that organizations face as part of their record keeping is the ability to maintain positive physical control of records on file; more so with organizations such as healthcare facilities that have to manage thousands of records. Because various people, such as doctors, nurses, and administrative personnel handle medical records, files tend to be misplaced or misfiled on occasion. RFID tags on medical files will not only preclude the loss/misplacement of a medical record, but it has the potential to increase efficiency and save the man-hours involved when searching for a known misplaced file. Additionally, performing inventories of files can conceivably take a few minutes since readers can read numerous tags per second. Although we are moving towards digitization of data, most healthcare facilities still use manual forms and records due to privacy issues and to prevent hackers or outsiders from accessing information from a hospital's database. DoD MTFs currently use manual records to maintain a patient's health history, in part because DoD members and dependents move constantly and have to physically transport the records in their possession to their new duty station.

Privacy is still a big issue, and putting patient health information in an RFID tag is not appropriate at this time because any person with a Radio Frequency (RF) hand-held reader can conceivably read tags within his proximity. Therefore, we suggest that the tag act as a license plate to retrieve data from the hospital's database for tracking purposes. For example, a tag can be written with a patient's unique ID number that would reference a specific ID number to a specific patient in the hospital's database. To prevent duplication of ID numbers, a number-letter sequence that includes birth month and year, initials, and last four digits of a person's social security number, i.e., 0867JAS5268, is suggested. With this numbering scheme, it is highly unlikely that a duplicate ID number will be issued, and furthermore, this information would be worthless to an outsider with an RF reading device. As RFID continues to mature and decrease in price, a smart tag could be affixed containing healthcare information from a patient's record that would alert a records technician automatically when a patient is due for a physical exam, or that

his HIV test is out of date, among countless other medical, time-critical requirements in order to contact the patient and schedule him/her with an appointment.

I, LCDR Sánchez, can personally remember a time when an RFID attached to a medical record would have saved me time and my CO some anguish. I was the Supply Officer onboard USS George Philip (FFG 12), and my CO had recently completed a full physical examination at NMCSD. About three days later, my CO noticed that his medical record was not in his portfolio when he tried to turn it back in to our ship's medical department, and immediately contacted me to call NMCSD to locate his record. He contacted me because I am a staff officer and NMCSD has mostly staff officers, so he figured that I would relate better with them. I first called the office where NMCSD performs physical exams and explained to them the situation, and after they looked around without success, they took my telephone number and told me that they would contact me as soon as they found the record. A couple of days passed and my CO was getting anxious because his medical history record of 21 years was about to disappear and would have to somehow be reconstructed with minimal known information. All of a sudden, my CO shuffled around my daily work priorities and my most immediate priority was to find his record. I made more phone calls and of course, my priority was nowhere near the priorities of NMCSD personnel, but I got ahold of a person in records and traced back all the CO's appointments and the office phone numbers. I called the office where the CO's last appointment had been, and it turned out that they had his record in a pile awaiting delivery to central records. If my CO's record had had an RFID tag with the code of 0458CLW9635, this number could have been entered in the RFID record locator system the first time I called. In this fashion they might have been able to assure me that it was in zone 1, for example, to narrow my search and ease my CO's anxiety by letting him know that his record was still in NMCSD.

B. USAGE OF RFID IN PATIENTS

There are currently many opposition groups that are voicing their fears and opinions concerning their privacy as RFID becomes more popular. Opposition groups argue that ubiquitous tracking by anybody with a proper reader, without knowledge or

consent, can gain personal information.[19] This has led to many unanswered questions of what should be tagged and who should enforce a customer's rights to be notified when buying a product with a RFID tag. Although the concerns for privacy are valid, RFID usage with patients in MTFs offers the ability to collect valuable data that can be analyzed and used for process improvements. Additionally, patient safety is another aspect of healthcare that has been increasingly visible on the radarscope of healthcare management, and RFID offers potential solutions to be aware of safety problems.

1. Patient Tracking Through RFID

a. For Process Improvements

Increasing customer service and reducing waiting times for patients can mean increased profits for civilian healthcare facilities because the cycle time for a patient from the time he/she walks in to the time they exit can be reduced, leading to more individual appointments in a day. Regarding MTFs, the typical soldier, airman, marine, or sailor has the belief that MTFs are bureaucratic, and just to complete a scheduled visit could take half a day. Additionally, to schedule an appointment to be seen by a specialist usually requires a couple of weeks' advanced notice because MTFs are flooded with patients and new requests. It is in this scenario where RFID can be used to collect data from patients throughout his/her visit. A tag can be affixed to a patient arriving for care or an appointment via a bracelet that would house the RFID tag. The information of a patient's whereabouts would be recorded in a statistical database in detail to know exactly how long a patient waited to be called in for vital signs, how long that person sat in a waiting room waiting to be escorted to a consultation room, how long a patient waited in a room for a doctor to arrive, the consultation time, how long it took that patient to walk to the pharmacy, the wait in the pharmacy to receive medication, and so on.

If hundreds of patients can be tracked for statistical purposes, an MTF can identify bottlenecks in existing processes and the managers can make educated decisions based on the data collected. With this valuable data in hand, the manager would clearly

[19] Cavoukian, Ann Ph.D, "Tag, You're It: Privacy Implications of Radio Frequency Identification (RFID) Technology", Information and Privacy Commissioner/Ontario Report, February 2004, pp. 14

see what areas of the hospital are understaffed and which areas are overstaffed. The data collected could also provide the reason for the bottlenecks; such as was it that appointments were too close to each other, lack of medical equipment, or plainly not enough medical personnel to treat all patients in a timely manner. Regardless of the reason, a manager would have reliable data to make decisions that could possibly lead to improved customer service and reduced amount of time a patient spends in an MTF for a routine appointment or emergent care. By eliminating patient wait time and decreasing a patient's visit cycle time, more patients can be scheduled in a day, effectively improving the current system.

b. For Patient Security

All hospitals nowadays employ a means to ensure that newborn babies are "tagged" with a device that would set off an alarm if a newborn was taken away from a designated area without proper authorization. With RFID, we could go a step beyond and tag both the newborn baby and the mother via a bracelet that would have the same code written to both tags. With this system an MTF would now be assured that if a mother deliberately or mistakenly picked up a baby that was not hers an alarm would be triggered. Additionally, this would help to prevent any person not authorized to be in the maternity ward from picking up a baby and holding him/her without a maternity nurse or mom's approval. Authorized maternity ward nurses on shift would carry an RFID tag that would correspond with all tags, preventing false alarms to be triggered.

Another potential use is to track older patients with Alzheimer's disease that wander off without knowing where they are or where they are going. Ideally, MTFs would want to track patients who have mental disabilities and cannot care for themselves and could easily wander off. Additionally, restraint patients suffering from a mental breakdown and military detainees who visit MTFs for medical care are ideal candidates for tracking through RFID in the event they got loose and tried to evade, causing a serious potential risk to other patients.

I, LT Sergio Chávez, can remember a time at NMCSD when we had a patient suffering from Alzheimer's disease. As a newly commissioned young officer, I was stationed at the NMCSD. About four months into my assignment I was assigned as

the Officer of the Day (OOD) in late November 2000. I reported for duty at approximately 1600. I began my shift by making the rounds throughout the Medical Center, which consisted of going to all the buildings, visiting the different medical, surgical, pediatric, and psychiatry wards, and checking in with the security department. Rounds were usually done about every two hours. At approximately 2020 hours I had completed one of my rounds. I returned to my office upon completion, when the pager I was wearing started buzzing. I immediately called the Quarterdeck in response to the page.

I was informed that a patient was being reported missing. I quickly ran to the Quarterdeck to begin coordinating a search effort for this missing patient. We placed a page over the paging system to solicit all the personnel that was still available in the medical center in order to conduct a physical search. Additionally, we gathered all available personnel in the on-complex quarters to help in the search. We set up search parties to begin looking for the missing patient from one end of the medical center complex to the other. We notified the San Diego Police Department as well. There had been several sightings of the elderly patient throughout the evening. Apparently, the patient had been given a pass to leave with her husband off the medical center complex for the afternoon. They had both returned around 1700. They had been walking in one of the courtyards when the patient's husband stepped into the rest room. When he exited the restroom, she was gone. He searched for her in the immediate area; however, due to his age, he could not move very fast and tired very easily. He finally decided to report her missing to the ward where she was assigned at approximately 2025.

Our search continued on the medical center complex, going from building to building, floor to floor. At around 2245 we received a call from the San Diego Police Department stating that they had found an elderly lady wandering at a high school campus that was about a mile and a half away from the medical center complex. It appeared that she had fallen because she had scrapes and her clothes were soiled and ripped. When found, the police reported that the elderly patient stated, "I'm trying to get back to my hospital bed."

This incident is not very common. Luckily we were able to locate this patient in a reasonable amount of time. Hospitals don't lose track of many patients. Nonetheless, there are some that do get lost, just within a hospital's compound. With an infrastructure that uses RFID, for patient tracking, the whereabouts of patients could always be known virtually eliminating the possibility of loosing another patient.

2. Decreasing the Probability of Medication Errors in Patients

Numerous studies have been done as a result of the many deaths that have occurred in hospitals due to medical personnel giving the wrong medication to a patient or a medication that a patient was allergic to. Results from two studies of large samples of hospitals, one in New York using 1984 data, and another in Colorado and Utah using 1992 data, suggested that in 1997 alone, at least 44,000, and perhaps as many as 98,000 Americans died in hospitals due to medical errors due to medication.[20]

Currently doctors write their orders into a care plan, and it's the nurse's job to carry these orders out to the fullest and safest extent possible. However, when a department is short staffed, or wards are filled to capacity, caring for patients can become a challenging and exhausting task. With this exhaustion and the human error factor, mistakes in dosage and/or medications can occur and sometimes result in untimely deaths. There are currently procedures in place, but not much in the way of technology, that would alleviate this problem. An RFID chip can now be imbedded into a patient's wrist identification tag that can be used to store data such as a patient's stay, diagnosis record, doctor's orders, medical allergies, and medications given, along with medication instructions. All a nurse would have to do is be next to a patient, and a handheld PDA-type device would display the patient's identity and pertinent medical information, to include medication instructions. This RFID-enabled wrist tag would also allow doctors and nurses to track the whereabouts of patients if they have been gone too long.

The Food and Drug Administration (FDA) is also looking at possibly mandating that producers of pharmaceuticals tag their shipments with RFID tags by year 2007.[21]

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[20] http://books.nap.edu/html/to_err_is_human/Ch2.PDF, 19 October 2004.

[21] Food and Drug Administration report, "Combating Counterfeit Drugs", http://www.fda.gov/oc/initiatives/counterfeit/report02_04.html#report, January 2004

Should they tag each packaged pill with a tag, they can reduce medication errors since the patient's medication instructions would have to coincide with the information on the bottle of pills.

C. PHARMACEUTICAL INVENTORY MANAGEMENT

Logisticians are continuously searching for ways to improve inventory management, and the goal is to achieve 100% real time inventory accuracy at all times. The issue of inventory management is more important in hospitals with their pharmaceuticals due to the importance of patient safety and the high dollar value. Because DoD pharmaceutical expenses total in the billions of dollars, the DoD Office of the Inspector General recently conducted an inspection at MTFs concerning the management of pharmaceutical inventory procedures, which reported their findings on June 17, 2004.[22] The study found that MTFs were experiencing problems when it came to inventory levels, stock rotation, and identifying expired pharmaceuticals. Indeed, these problems affect most inventories, regardless of the product in stock.

With the continuous maturing of RFID technology, MTFs could implement smart shelves for pharmaceutical inventories. A smart shelf would contain RFID readers that would know exactly what is in stock all the time. For example, an RFID tag attached to a bottle of pills would contain the basic information as to what type of medicine it is, information on the manufacturer, date of manufacture, lot number, and expiration date. With this type of system, inventory management would require less man-hours because the information could be shared with the contracted prime vendor supplying the product and therefore, pre-established low limits could be set that would trigger automatic replenishments. In the DoD's Inspector General report findings, there were numerous MTFs that were stocking too many days of inventory on hand when the goal was five days. Excessive stock led to expired medication being on the shelves, which led, on occasions, to be dispensed to patients.[23] Sharing daily prescription issues and on-hand inventory levels with the prime vendor allows for both parties to analyze the data to

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[22] http://www.dodig.osd.mil/audit/reports/fy04/04-087.pdf, 19 October 2004.

[23] Ibid

further predict daily demand for products and could, therefore conceivably reduce inventory levels even further.

With an RFID infrastructure for pharmaceutical inventory, the system in place could be set to constantly update the inventory database, in which case, a medicine that would expire within 30 days would be displayed in red to alert a pharmacist to either issue this medication first or remove it from inventory. Since each RFID tag can be issued its own unique identification number, it would be simple to pinpoint a specific package or bottle of medicine. Regarding the issue of stock rotation, the database could be set to show, by date sequence, which bottle of medication would expire first, and as a consequence, pharmacists would know what medication to issue first to prevent shrinkage.

Another useful aspect of adopting RFID for pharmaceuticals is the ability to quickly identify recalled products. When pharmaceutical companies recall their product, they usually pull every single bottle in store and stock shelves for safety reasons. Once industry adopts RFID and tags the products to a bottle level, a recall can specifically identify which bottles, by lot number, are defective. In a MTF's database, a pharmacist would query the database for the specific lot number, and the smart shelf readers would query all inventory on hand for that specific lot number in a matter of seconds. Additionally, the FDA has mandated that pharmaceutical companies use RFID in their supply chain by 2007 to prevent counterfeiting of drugs, which, according to the report, is a problem that continues to grow.[24] The FDA mandate will make RFID a viable solution for MTFs to inventory pharmaceuticals via smart RFID-enabled shelves.

D. TRACKING DONATED BLOOD

Human blood has always been and always will be a precious commodity whenever a disaster occurs, or whenever a medical condition exists that requires a blood donation to continue a person's life. Having that blood in the right place at the right time

[24] Food and Drug Administration report, "Combating Counterfeit Drugs", http://www.fda.gov/oc/initiatives/counterfeit/report02_04.html#report, January 2004

is crucial to the sustainability of life to the person in need. So why is it that in this day and time, with all of the technology that exists, we still have trouble tracking the blood supply that exists nationally, statewide, regionally, citywide, and even within a MTF?

There are systems that exist, but most exist within the individual organization that oversees the blood donation program. There is currently a system that exists called the Joint Medical Asset Repository (JMAR). However, after the attacks on September 11, 2001, the Department of Health and Human Services had to rely on paper, pencil, phone, and fax to activate emergency plans to transfer medical volunteers and supplies to New York City.[25] According to Colonel G. Michael Fitzpatrick, director of the Armed Services Blood Program Office, there is no nationwide computerized network for over half of the nation's blood donations.[26] Within the DoD there is the Defense Blood Standard System, which uses a client/server to help the facilities track their blood supplies. These systems, however, are not interconnected with other DoD facilities, so it's strictly in-house.

The process that currently exists, at least within the DoD, is that when a person goes to give blood, they fill out an initial questionnaire that contains a barcode at the bottom of the form.[27] After filling out the questionnaire, it is reviewed to ensure that the person trying to donate is able to donate within the guidelines set. If the person is deemed unqualified to donate, then the barcode associated with that person is destroyed and the person is entered into the Defense Blood Standards System (DBSS) as deferred from donation. If the person is qualified as a donor, the barcode is then removed from the form and attached to the bag of blood that the donor is giving. From there the blood is refrigerated and sent to the lab, where the lab spins the donated blood into plasma, platelets, and packed red blood cells. A barcode is then attached to each of these, tracing them back to the initial donor. Vials of blood are also drawn before the donor is hooked

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[25] Hasson, Judi; "Blood-tracking Systems Fragmented," Sept. 17, 2001 www.fcw.com/fcw/articles/2001/0917/web-blood-09-17-01.asp

[26] Ibid

[27] Phone interview with LT Todd Tetreault, Medical Service Corps, USNR, Oct. 27, 2004

up to a bag. These vials are used to test the blood for any viral antibodies, and again, barcodes are placed on each vial, tracking the particular vial back to the original donor.

Once production and quality assurance are complete, an FDA face label, which also contains another barcode, is attached to each blood product and transported to a treatment facility. [28]

If RFID were used, the manufacturer of each bag could produce the empty bag with an RFID tag already affixed to it. Once the donation site received the bag, all they would have to do is write to the tag the blood type, where the blood was donated, and from whom it was taken. Once this information is written to the tag, donated blood can be tracked through RFID readers as it is shipped and disbursed throughout the country. There is currently no real-time tracking system that will identify a specific blood bag all the way from when it is taken from the donation site, to the central control point, to the facility who will use it, and ultimately to the department that ordered it. Using temperature-sensing RFID tags to track donated blood is another benefit in that a temperature history will be recorded on the chip, which will alert medical personnel if the blood reached an unsafe temperature through its short shelf life span. Temperature-sensing tags can dramatically reduce the probability of using spoiled blood that has been exposed to temperatures that are out of the required range on a patient. The temperature-sensing RFID tag used for tracking and temperature control has the potential to do away with all of the bar codes that are currently required.

One of the main concerns with RFID tags is that of patient personal information and privacy. Since this technology would collect donor information, as well as patient information, it remains a concern and will continue to as long as the technology is vulnerable to unauthorized access. By this I mean that anyone holding a handheld reader could derive who gave the blood, if the blood was infected with anything, to whom the blood would be going, and possibly why the blood was needed (i.e., upcoming procedure). As these issues are worked out it is plain to see how the implementation of

[28] Ibid

this technology would truly help to increase patient standard of care and blood tracking. Until then we will have to stay with the existing bar-coding technology.

To go along with the RFID tagging, a major initiative would have to be undertaken to form a national database that would store all of the information from the tags, which would need to be standardized. For a national database to be set up, each individual site would have to be outfitted with a server that would ultimately update a master server located somewhere, such as the national headquarters for the American Red Cross, in Washington D.C. Authorized users would have access to this national database and be able to locate blood more readily. An additional requirement would be that each facility that received blood, took donations of blood, or stored blood would have to have interrogators to enable them to read the tags.

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VII. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

It is evident by our analysis that the potential benefits associated by deploying an RFID system to track and manage equipment within NMCSD leads to realized cost savings by eliminating lost equipment replacement costs, as well as better utilizing personnel to perform other duties. Based on our sensitivity analysis, our data shows that an investment of $1,255,138 would be recouped within the first year, as we have shown by performing various analyses using several assumptions. Furthermore, by running all ROI analyses to six years and calculating a NPV with a cost of money of 4.5%, NMCSD would save a substantial amount of capital in equipment replacement costs in the out years. Tracking medical equipment by utilizing RFID technology will not only save NMCSD money, but it will aid in conforming to inventory regulations in that scheduled inventories to include wall-to-wall would now be able to be performed from a desk within a couple of days -- if not in a day -- rather than by deploying personnel to search for equipment and tacking as much as three to six months to locate all equipment without guaranteeing 100% accuracy. Implementing this technology within NMCSD and other medical treatment facilities will benefit BUMED as whole in that it will be able to reduce equipment replacement costs, as well as utilizing personnel efficiently.

B. RECOMMENDATIONS

We also recommend that a pilot study be performed at a smaller MTF by implementing an RFID infrastructure to test our analysis. It is our recommendation that the pilot be implemented either at Naval Hospital, Lemoore, CA (small facility), or Naval Hospital, Camp Pendleton, CA (intermediate sized facility). We chose either of these facilities due to their size (bed capacity, and physical size) and proximity to NMCSD. By using a smaller MTF, implementation will be quicker and the cost will obviously be less. Additionally, established research metrics can be easily measured and followed at a smaller MTF.

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APPENDIX A. SURVEY

Inventory Management/Biomedical Repair Questionnaire

1. What is your current Rate and Pay grade? (e.g., SH3/E4)

2. What is your primary duty?

3. How long have you been performing your current duties? (Please answer in years and months.)

4. On average how much of your day is spent looking for equipment? (Please provide answer in hours and minutes.)

5. On average, how much time would you estimate that you spend searching for an **individual piece** of medical equipment? (Please provide answer in hours and minutes.)

6. What is your best estimate for time spent looking for the following items (i.e., specific serial number)? (Please provide answer in hours and minutes.)

    - Blood Analyzer
    - Defibrillator
    - Heart Monitors
    - Infusion Pumps
    - ElectroCardiogram (EKG)
    - Vital Signs Machine

7. At what point do you feel that you've exhausted all of your resources in searching for an item listed above and decide to forward the issue up your chain of command? (Please answer in days and hours.)

8. Rating the equipment from 1 to 5, 1 being unfamiliar, 5 being very familiar, how comfortable do you feel identifying different pieces of medical equipment when you enter a space?

9. Using the scale below, how often do you require assistance from personnel within other departments?

0%	25%	50%	75%	100%

a) On average, what is the typical pay grade of the individual assisting you?

APPENDIX B. QUESTIONNAIRES RECEIVED

Respondent 1

SHANEFELT, J

Inventory Management/Bio-Medical Repair Questionnaire

1. What is your current Rate and Paygrade? (e.g., SH3/E4) E-4
2. What is your primary duty? Inputs
3. How long have you been performing your current duties? (Please answer in years and months) 2 years 3 month
4. On average how much of your day is spent looking for equipment? (please provide answer in hours and minutes) 2 hours 30 min.
5. On average how much time would you estimate that you spend searching for an **individual piece** of medical equipment? (please provide answer in hours and minutes) 1 hour
6. What is your best estimate for time spent looking for the following items (i.e. specific serial number)? (please provide answer in hours and minutes)
   - Blood Analyzer ~ 1 hr
   - Defibrillator 2 hr
   - Heart Monitors 30 min.
   - Infusion Pumps 25 min.
   - Electro Cardiogram (EKG) 18 min.
   - Vital Signs Machine 7 min.
7. At what point do you feel that you've exhausted all of your resources in searching for an item listed above and decide to forward the issue up your chain of command? (Please answer in days and hours) 8 days
8. Rating the equipment from 1 to 5, 1 being unfamiliar, 5 being very familiar, how comfortable do you feel identifying different pieces of medical equipment when you enter a space? 4

8. Using the scale below, how often do you require assistance from personnel within other department?

0%	25%	50%	75%	100%

a) On average, what is the typical paygrade of the individual assisting you?

E-5

Respondent 2

Inventory Management/Bio-Medical Repair Questionnaire

1. What is your current Rate and Paygrade? (e.g., SH3/E4)
   SH3/E4
2. What is your primary duty?
   DISPOSAL COMPUTER AND MED. EQUIPMENT
3. How long have you been performing your current duties? (Please answer in years and months)
   1 yr. 4 month.
4. On average how much of your day is spent looking for equipment? (please provide answer in hours and minutes)
5. On average how much time would you estimate that you spend searching for an **individual piece** of medical equipment? (please provide answer in hours and minutes)
6. What is your best estimate for time spent looking for the following items (i.e. specific serial number)? (please provide answer in hours and minutes)
   - Blood Analyzer
   - Defibrillator
   - Heart Monitors
   - Infusion Pumps
   - Electro Cardiogram (EKG)
   - Vital Signs Machine
7. At what point do you feel that you've exhausted all of your resources in searching for an item listed above and decide to forward the issue up your chain of command? (Please answer in days and hours) 5 day.
8. Rating the equipment from 1 to 5, 1 being unfamiliar, 5 being very familiar, how comfortable do you feel identifying different pieces of medical equipment when you enter a space? 2.

8. Using the scale below, how often do you require assistance from personnel within other department? 75%

0%	25%	50%	75%	100%

a) On average, what is the typical paygrade of the individual assisting you?
E-5

Respondent 3

Inventory Management/Bio-Medical Repair Questionnaire

1. What is your current Rate and Paygrade? (e.g., SH3/E4) SH2/E5
2. What is your primary duty? DLMSS/DPAS manager
3. How long have you been performing your current duties? (Please answer in years and months) 3yrs
4. On average how much of your day is spent looking for equipment? (please provide answer in hours and minutes) 4
5. On average how much time would you estimate that you spend searching for an **individual piece** of medical equipment? (please provide answer in hours and minutes) 2
6. What is your best estimate for time spent looking for the following items (i.e. specific serial number)? (please provide answer in hours and minutes)
   - Blood Analyzer 2
   - Defibrillator /
   - Heart Monitors 30min
   - Infusion Pumps 30 min
   - Electro Cardiogram (EKG) /
   - Vital Signs Machine 30min
7. At what point do you feel that you've exhausted all of your resources in searching for an item listed above and decide to forward the issue up your chain of command? (Please answer in days and hours) 3days
8. Rating the equipment from 1 to 5, 1 being unfamiliar, 5 being very familiar, how comfortable do you feel identifying different pieces of medical equipment when you enter a space? /

8. Using the scale below, how often do you require assistance from personnel within other department?

			✓	
0%	25%	50%	75%	100%

a) On average, what is the typical paygrade of the individual assisting you?

E-5

Respondent 4

Inventory Management/Bio-Medical Repair Questionnaire

1. What is your current Rate and Paygrade? (e.g., SH3/E4)
2. What is your primary duty? DMLSS / DPAS
3. How long have you been performing your current duties? (Please answer in years and months) 2 YRS
4. On average how much of your day is spent looking for equipment? (please provide answer in hours and minutes) 3 HRS.
5. On average how much time would you estimate that you spend searching for an **individual piece** of medical equipment? (please provide answer in hours and minutes) 1 HR.
6. What is your best estimate for time spent looking for the following items (i.e. specific serial number)? (please provide answer in hours and minutes)
   - Blood Analyzer 1 HR.
   - Defibrillator 1 HR.
   - Heart Monitors 1 HR.
   - Infusion Pumps 1 HR
   - Electro Cardiogram (EKG) 1 HR.
   - Vital Signs Machine 1 HR.
7. At what point do you feel that you've exhausted all of your resources in searching for an item listed above and decide to forward the issue up your chain of command? (Please answer in days and hours) 5 DAYS
8. Rating the equipment from 1 to 5, 1 being unfamiliar, 5 being very familiar, how comfortable do you feel identifying different pieces of medical equipment when you enter a space? 2

8. Using the scale below, how often do you require assistance from personnel within other department?

0%	25%	50%	75%	100%

a) On average, what is the typical paygrade of the individual assisting you?

E-4

Respondent 5

JASE, CLINTON

Inventory Management/Bio-Medical Repair Questionnaire

1. What is your current Rate and Paygrade? (e.g., SH3/E4) SH2
2. What is your primary duty? PROP "D" PROP "A"
3. How long have you been performing your current duties? (Please answer in years and months) 2 yrs
4. On average how much of your day is spent looking for equipment? (please provide answer in hours and minutes) 8hrs
5. On average how much time would you estimate that you spend searching for an **individual piece** of medical equipment? (please provide answer in hours and minutes) 3MIN
6. What is your best estimate for time spent looking for the following items (i.e. specific serial number)? (please provide answer in hours and minutes)
   - Blood Analyzer 20MIN
   - Defibrillator 20MIN
   - Heart Monitors 20MIN
   - Infusion Pumps 20MIN
   - Electro Cardiogram (EKG) 20MIN
   - Vital Signs Machine 20MIN
7. At what point do you feel that you've exhausted all of your resources in searching for an item listed above and decide to forward the issue up your chain of command? (Please answer in days and hours)
8. Rating the equipment from 1 to 5, 1 being unfamiliar, 5 being very familiar, how comfortable do you feel identifying different pieces of medical equipment when you enter a space? 2

8. Using the scale below, how often do you require assistance from personnel within other department?

		✓		
0%	25%	50%	75%	100%

a) On average, what is the typical paygrade of the individual assisting you? E-5

Respondent 6

Inventory Management/Bio-Medical Repair Questionnaire

1. What is your current Rate and Paygrade? (e.g., SH3/E4) SH3 / E4
2. What is your primary duty? Prop. Disposal
3. How long have you been performing your current duties? (Please answer in years and months) 1 month
4. On average how much of your day is spent looking for equipment? (please provide answer in hours and minutes) N/A
5. On average how much time would you estimate that you spend searching for an **individual piece** of medical equipment? (please provide answer in hours and minutes) N/A
6. What is your best estimate for time spent looking for the following items (i.e. specific serial number)? (please provide answer in hours and minutes)
   - Blood Analyzer
   - Defibrillator
   - Heart Monitors
   - Infusion Pumps
   - Electro Cardiogram (EKG)
   - Vital Signs Machine

   N/A
7. At what point do you feel that you've exhausted all of your resources in searching for an item listed above and decide to forward the issue up your chain of command? (Please answer in days and hours)
8. Rating the equipment from 1 to 5, 1 being unfamiliar, 5 being very familiar, how comfortable do you feel identifying different pieces of medical equipment when you enter a space? 5

8. Using the scale below, how often do you require assistance from personnel within other department?

0%	25%	50%	75%	100%

a) On average, what is the typical paygrade of the individual assisting you?

E-5

Respondent 7

Inventory Management/Bio-Medical Repair Questionnaire

1. What is your current Rate and Paygrade? (e.g., SH3/E4) SK3/E4
2. What is your primary duty? PROPERTY DISPOSAL
3. How long have you been performing your current duties? (Please answer in years and months) 1 MONTH
4. On average how much of your day is spent looking for equipment? (please provide answer in hours and minutes) NA
5. On average how much time would you estimate that you spend searching for an **individual piece** of medical equipment? (please provide answer in hours and minutes) NA
6. What is your best estimate for time spent looking for the following items (i.e. specific serial number)? (please provide answer in hours and minutes)
   - Blood Analyzer
   - Defibrillator
   - Heart Monitors
   - Infusion Pumps
   - Electro Cardiogram (EKG)
   - Vital Signs Machine

   NA
7. At what point do you feel that you've exhausted all of your resources in searching for an item listed above and decide to forward the issue up your chain of command? (Please answer in days and hours) NA
8. Rating the equipment from 1 to 5, 1 being unfamiliar, 5 being very familiar, how comfortable do you feel identifying different pieces of medical equipment when you enter a space? NA

8. Using the scale below, how often do you require assistance from personnel within other department? NA

0%	25%	50%	75%	100%

a) On average, what is the typical paygrade of the individual assisting you?

NA

Respondent 8

Inventory Management/Bio-Medical Repair Questionnaire

1. What is your current Rate and Paygrade? (e.g., SH3/E4) SA^3/E4
2. What is your primary duty? PROPERTY DISPOSAL
3. How long have you been performing your current duties? (Please answer in years and months) 18 DAYS
4. On average how much of your day is spent looking for equipment? (please provide answer in hours and minutes) N/A
5. On average how much time would you estimate that you spend searching for an **individual piece** of medical equipment? (please provide answer in hours and minutes) N/A
6. What is your best estimate for time spent looking for the following items (i.e. specific serial number)? (please provide answer in hours and minutes)
   - Blood Analyzer N/A
   - Defibrillator N/A
   - Heart Monitors N/A
   - Infusion Pumps N/A
   - Electro Cardiogram (EKG) N/A
   - Vital Signs Machine N/A
7. At what point do you feel that you've exhausted all of your resources in searching for an item listed above and decide to forward the issue up your chain of command? (Please answer in days and hours) N/A
8. Rating the equipment from 1 to 5, 1 being unfamiliar, 5 being very familiar, how comfortable do you feel identifying different pieces of medical equipment when you enter a space? N/A

8. Using the scale below, how often do you require assistance from personnel within other department? N/A

0%	25%	50%	75%	100%

a) On average, what is the typical paygrade of the individual assisting you?
N/A

Respondent 9

Inventory Management/Bio-Medical Repair Questionnaire

1. What is your current Rate and Paygrade? (e.g., SH3/E4)
   HM2 / E-5
2. What is your primary duty?
   ~~2 years~~ Repair Equip
3. How long have you been performing your current duties? (Please answer in years and months) 2 years
4. On average how much of your day is spent looking for equipment? (please provide answer in hours and minutes) 2hr. 30 min
5. On average how much time would you estimate that you spend searching for an **individual piece** of medical equipment? (please provide answer in hours and minutes) 1hr 15 min
6. What is your best estimate for time spent looking for the following items (i.e. specific serial number)? (please provide answer in hours and minutes)
   - Blood Analyzer 10 min
   - Defibrillator 5 min
   - Heart Monitors 15 min
   - Infusion Pumps 1hr
   - Electro Cardiogram (EKG) 30 min
   - Vital Signs Machine 30 min
7. At what point do you feel that you've exhausted all of your resources in searching for an item listed above and decide to forward the issue up your chain of command? (Please answer in days and hours) 14 days
8. Rating the equipment from 1 to 5, 1 being unfamiliar, 5 being very familiar, how comfortable do you feel identifying different pieces of medical equipment when you enter a space? 4

8. Using the scale below, how often do you require assistance from personnel within other department?

	X			
0%	25%	50%	75%	100%

a) On average, what is the typical paygrade of the individual assisting you?
E-4

Respondent 10

Inventory Management/Bio-Medical Repair Questionnaire

1. What is your current Rate and Paygrade? (e.g., SH3/E4) E-4
2. What is your primary duty? Medical Repair technician
3. How long have you been performing your current duties? (Please answer in years and months) 4 yrs
4. On average how much of your day is spent looking for equipment? (please provide answer in hours and minutes) 3hrs
5. On average how much time would you estimate that you spend searching for an **individual piece** of medical equipment? (please provide answer in hours and minutes) 10min
6. What is your best estimate for time spent looking for the following items (i.e. specific serial number)? (please provide answer in hours and minutes)
   - Blood Analyzer ½ hr
   - Defibrillator ½ hr
   - Heart Monitors ½ hr
   - Infusion Pumps ½ hr
   - Electro Cardiogram (EKG) ½ hr
   - Vital Signs Machine ½ hr
7. At what point do you feel that you've exhausted all of your resources in searching for an item listed above and decide to forward the issue up your chain of command? (Please answer in days and hours) Usually by the 3rd week of the month and after consulting supply P.O.
8. Rating the equipment from 1 to 5, 1 being unfamiliar, 5 being very familiar, how comfortable do you feel identifying different pieces of medical equipment when you enter a space?

8. Using the scale below, how often do you require assistance from personnel within other department?

			✓	
0%	25%	50%	75%	100%

a) On average, what is the typical paygrade of the individual assisting you?

E-5

Respondent 11

Inventory Management/Bio-Medical Repair Questionnaire

1. What is your current Rate and Paygrade? (e.g., SH3/E4) HM2/E5
2. What is your primary duty? Med Repair
3. How long have you been performing your current duties? (Please answer in years and months) 4 yrs 2 mos
4. On average how much of your day is spent looking for equipment? (please provide answer in hours and minutes) 3 Hours
5. On average how much time would you estimate that you spend searching for an **individual piece** of medical equipment? (please provide answer in hours and minutes) 30 minutes
6. What is your best estimate for time spent looking for the following items (i.e. specific serial number)? (please provide answer in hours and minutes)
   - Blood Analyzer – 20 minutes
   - Defibrillator – 5 minutes
   - Heart Monitors – 30 minutes
   - Infusion Pumps – 25 minutes
   - Electro Cardiogram (EKG) – 15 minutes
   - Vital Signs Machine – 20 minutes
7. At what point do you feel that you've exhausted all of your resources in searching for an item listed above and decide to forward the issue up your chain of command? (Please answer in days and hours) 15 days, 3 Hours
8. Rating the equipment from 1 to 5, 1 being unfamiliar, 5 being very familiar, how comfortable do you feel identifying different pieces of medical equipment when you enter a space? 4

8. Using the scale below, how often do you require assistance from personnel within other department? 75%

0%	25%	50%	75%	100%

a) On average, what is the typical paygrade of the individual assisting you?

E4

Respondent 12

Inventory Management/Bio-Medical Repair Questionnaire

1. What is your current Rate and Paygrade? (e.g., SH3/E4)
   HM3/E4
2. What is your primary duty?
   BIOMED TECH.
3. How long have you been performing your current duties? (Please answer in years and months)
   9 MONTHS
4. On average how much of your day is spent looking for equipment? (please provide answer in hours and minutes)
   1 HOUR & 15 MINUTES
5. On average how much time would you estimate that you spend searching for an **individual piece** of medical equipment? (please provide answer in hours and minutes)
   20 MINUTES
6. What is your best estimate for time spent looking for the following items (i.e. specific serial number)? (please provide answer in hours and minutes)
   - Blood Analyzer 10 MINS.
   - Defibrillator 10 MINS.
   - Heart Monitors 45 MINS.
   - Infusion Pumps 45 MINS.
   - Electro Cardiogram (EKG) 5 MINS.
   - Vital Signs Machine 45 MINS.
7. At what point do you feel that you've exhausted all of your resources in searching for an item listed above and decide to forward the issue up your chain of command? (Please answer in days and hours) 14 DAYS & 3 HOURS / 15 MINS & 41 SECS.
8. Rating the equipment from 1 to 5, 1 being unfamiliar, 5 being very familiar, how comfortable do you feel identifying different pieces of medical equipment when you enter a space? 5

8. Using the scale below, how often do you require assistance from personnel within other department?

0%	25%	50%	75%	100%

a) On average, what is the typical paygrade of the individual assisting you?
   E-4 & E-5

Respondent 13

Inventory Management/Bio-Medical Repair Questionnaire

1. What is your current Rate and Paygrade? (e.g., SH3/E4) E-6/HM1
2. What is your primary duty? Team Leader of Team 2 (PM's, Repair) Medical Equi. repair
3. How long have you been performing your current duties? (Please answer in years and months) 3yrs. & 5 months
4. On average how much of your day is spent looking for equipment? (please provide answer in hours and minutes) 4 hours
5. On average how much time would you estimate that you spend searching for an **individual piece** of medical equipment? (please provide answer in hours and minutes)
6. What is your best estimate for time spent looking for the following items (i.e. specific serial number)? (please provide answer in hours and minutes)
   - Blood Analyzer 20 min.
   - Defibrillator 5 min.
   - Heart Monitors 45 min.
   - Infusion Pumps 30 min.
   - Electro Cardiogram (EKG) - 10 min.
   - Vital Signs Machine 20 min.
7. At what point do you feel that you've exhausted all of your resources in searching for an item listed above and decide to forward the issue up your chain of command? (Please answer in days and hours) 14 days
8. Rating the equipment from 1 to 5, 1 being unfamiliar, 5 being very familiar, how comfortable do you feel identifying different pieces of medical equipment when you enter a space? 4

8. Using the scale below, how often do you require assistance from personnel within other department?

0%	25%	50%	(75%)	100%

a) On average, what is the typical paygrade of the individual assisting you?
E-4, E-5, E-6

Respondent 14

Inventory Management/Bio-Medical Repair Questionnaire

1. What is your current Rate and Paygrade? (e.g., SH3/E4)
   HM3 / E4
2. What is your primary duty?
   MEDICAL REPAIR
3. How long have you been performing your current duties? (Please answer in years and months) 1yr 8 months
4. On average how much of your day is spent looking for equipment? (please provide answer in hours and minutes) 2-3 hours
5. On average how much time would you estimate that you spend searching for an **individual piece** of medical equipment? (please provide answer in hours and minutes)
   1hr
6. What is your best estimate for time spent looking for the following items (i.e. specific serial number)? (please provide answer in hours and minutes)
   - Blood Analyzer 15 min
   - Defibrillator 5 min
   - Heart Monitors 10 min
   - Infusion Pumps 1 hr.
   - Electro Cardiogram (EKG) 15 min
   - Vital Signs Machine 30 min
7. At what point do you feel that you've exhausted all of your resources in searching for an item listed above and decide to forward the issue up your chain of command? (Please answer in days and hours) 5 to 7 days during pm's.
   1 to 2 days unscheduled.
8. Rating the equipment from 1 to 5, 1 being unfamiliar, 5 being very familiar, how comfortable do you feel identifying different pieces of medical equipment when you enter a space? 4

8. Using the scale below, how often do you require assistance from personnel within other department?

0%	25%	50%	75%	100%

a) On average, what is the typical paygrade of the individual assisting you?
   E-5

Respondent 15

Inventory Management/Bio-Medical Repair Questionnaire

1. What is your current Rate and Paygrade? (e.g., SH3/E4)
   HM2 / E5
2. What is your primary duty?
   Med Repair
3. How long have you been performing your current duties? (Please answer in years and months) 1 yr. 6 mo.
4. On average how much of your day is spent looking for equipment? (please provide answer in hours and minutes) 2 hrs.
5. On average how much time would you estimate that you spend searching for an **individual piece** of medical equipment? (please provide answer in hours and minutes)
   30 min.
6. What is your best estimate for time spent looking for the following items (i.e. specific serial number)? (please provide answer in hours and minutes)
   - Blood Analyzer
     5 min.
   - Defibrillator -
     1 min
   - Heart Monitors
     30 min
   - Infusion Pumps
     1 hr.
   - Electro Cardiogram (EKG)
     30 min
   - Vital Signs Machine
     1 hr.
7. At what point do you feel that you've exhausted all of your resources in searching for an item listed above and decide to forward the issue up your chain of command? (Please answer in days and hours)
   End of Monthly PMs
8. Rating the equipment from 1 to 5, 1 being unfamiliar, 5 being very familiar, how comfortable do you feel identifying different pieces of medical equipment when you enter a space? 3

8. Using the scale below, how often do you require assistance from personnel within other department?

0%	25%	50% X	75%	100%

a) On average, what is the typical paygrade of the individual assisting you?
   E4

Respondent 16

Inventory Management/Bio-Medical Repair Questionnaire

1. What is your current Rate and Paygrade? (e.g., SH3/E4)
   HM1/E6
2. What is your primary duty?
   MED-REPAIR
3. How long have you been performing your current duties? (Please answer in years and months)
   10YR
4. On average how much of your day is spent looking for equipment? (please provide answer in hours and minutes)
   1 to 2 hours
5. On average how much time would you estimate that you spend searching for an **individual piece** of medical equipment? (please provide answer in hours and minutes)
   SAME AS # 4
6. What is your best estimate for time spent looking for the following items (i.e. specific serial number)? (please provide answer in hours and minutes)
   - Blood Analyzer 10-15 minutes
   - Defibrillator 10-15 minutes
   - Heart Monitors 15-30 minutes
   - Infusion Pumps 4-5 hours
   - Electro Cardiogram (EKG) 2-3 hours
   - Vital Signs Machine 2-3 hours
7. At what point do you feel that you've exhausted all of your resources in searching for an item listed above and decide to forward the issue up your chain of command? (Please answer in days and hours)
   14 day 30 minutes and 14Sec
8. Rating the equipment from 1 to 5, 1 being unfamiliar, 5 being very familiar, how comfortable do you feel identifying different pieces of medical equipment when you enter a space?
   5

8. Using the scale below, how often do you require assistance from personnel within other department?

	✓				
0%	10%	25%	50%	75%	100%

a) On average, what is the typical paygrade of the individual assisting you?
   E4 and below

Respondent 17

Inventory Management/Bio-Medical Repair Questionnaire

1. What is your current Rate and Paygrade? (e.g., SH3/E4)
   HM2 / E5
2. What is your primary duty?
   BMET
3. How long have you been performing your current duties? (Please answer in years and months)
   1 yr 2 mos
4. On average how much of your day is spent looking for equipment? (please provide answer in hours and minutes)
   5 hrs
5. On average how much time would you estimate that you spend searching for an **individual piece** of medical equipment? (please provide answer in hours and minutes)
   30
6. What is your best estimate for time spent looking for the following items (i.e. specific serial number)? (please provide answer in hours and minutes)
   - Blood Analyzer 1 hr
   - Defibrillator 15 min
   - Heart Monitors 1 hr
   - Infusion Pumps 2 days = 48 hrs
   - Electro Cardiogram (EKG) 1 hr
   - Vital Signs Machine 24 hrs
7. At what point do you feel that you've exhausted all of your resources in searching for an item listed above and decide to forward the issue up your chain of command? (Please answer in days and hours)
   2 wks
8. Rating the equipment from 1 to 5, 1 being unfamiliar, 5 being very familiar, how comfortable do you feel identifying different pieces of medical equipment when you enter a space?
   4

8. Using the scale below, how often do you require assistance from personnel within other department?

0%	25%	50%	75%	100%

a) On average, what is the typical paygrade of the individual assisting you?
   E4

Respondent 18

Inventory Management/Bio-Medical Repair Questionnaire

1. What is your current Rate and Paygrade? (e.g., SH3/E4) HM^2 / E5
2. What is your primary duty? BMET
3. How long have you been performing your current duties? (Please answer in years and months) 2 YEARS
4. On average how much of your day is spent looking for equipment? (please provide answer in hours and minutes) 3 HOURS
5. On average how much time would you estimate that you spend searching for an **individual piece** of medical equipment? (please provide answer in hours and minutes) 30 MINS
6. What is your best estimate for time spent looking for the following items (i.e. specific serial number)? (please provide answer in hours and minutes)
   - Blood Analyzer 1 HR
   - Defibrillator 30 MIN
   - Heart Monitors 30 MIN
   - Infusion Pumps 24 HRS
   - Electro Cardiogram (EKG) 1 HR
   - Vital Signs Machine 12 HRS
7. At what point do you feel that you've exhausted all of your resources in searching for an item listed above and decide to forward the issue up your chain of command? (Please answer in days and hours) 3 DAYS
8. Rating the equipment from 1 to 5, 1 being unfamiliar, 5 being very familiar, how comfortable do you feel identifying different pieces of medical equipment when you enter a space? 4.5

8. Using the scale below, how often do you require assistance from personnel within other department?

0%	25%	50%	75%	100%

a) On average, what is the typical paygrade of the individual assisting you?

E4

Respondent 19

Inventory Management/Bio-Medical Repair Questionnaire

1. What is your current Rate and Paygrade? (e.g., SH3/E4)
   HM2 /E5
2. What is your primary duty?
   BASIC BMET
3. How long have you been performing your current duties? (Please answer in years and months)
   2 YEARS
4. On average how much of your day is spent looking for equipment? (please provide answer in hours and minutes)
   5 HRS
5. On average how much time would you estimate that you spend searching for an **individual piece** of medical equipment? (please provide answer in hours and minutes)
   45 MIN.
6. What is your best estimate for time spent looking for the following items (i.e. specific serial number)? (please provide answer in hours and minutes)

   - Blood Analyzer - 1 HR
   - Defibrillator - 30 MIN
   - Heart Monitors - 1HR
   - Infusion Pumps - 48 HRS
   - Electro Cardiogram (EKG) - 1HR
   - Vital Signs Machine - 24 HRS

7. At what point do you feel that you've exhausted all of your resources in searching for an item listed above and decide to forward the issue up your chain of command? (Please answer in days and hours)
   2 WEEKS
8. Rating the equipment from 1 to 5, 1 being unfamiliar, 5 being very familiar, how comfortable do you feel identifying different pieces of medical equipment when you enter a space? 4.5

8. Using the scale below, how often do you require assistance from personnel within other department?

0%	25%	50%	75%	100%

a) On average, what is the typical paygrade of the individual assisting you?
   HN JOHNSON

   E5 ↑

Respondent 20

Inventory Management/Bio-Medical Repair Questionnaire

1. What is your current Rate and Paygrade? (e.g., SH3/E4)
   HM 2/ E5
2. What is your primary duty?
   BASIC BMET
3. How long have you been performing your current duties? (Please answer in years and months) 3 YRS
4. On average how much of your day is spent looking for equipment? (please provide answer in hours and minutes) 2 WEEKS
5. On average how much time would you estimate that you spend searching for an **individual piece** of medical equipment? (please provide answer in hours and minutes)
   3 WEEKS
6. What is your best estimate for time spent looking for the following items (i.e. specific serial number)? (please provide answer in hours and minutes)
   - Blood Analyzer 30 MIN
   - Defibrillator 2 DAYS
   - Heart Monitors 30 MIN
   - Infusion Pumps 1 - 2 WEEKS
   - Electro Cardiogram (EKG) 2 HOURS
   - Vital Signs Machine 1 - 2 WEEKS
7. At what point do you feel that you've exhausted all of your resources in searching for an item listed above and decide to forward the issue up your chain of command? (Please answer in days and hours) 3 WEEKS
8. Rating the equipment from 1 to 5, 1 being unfamiliar, 5 being very familiar, how comfortable do you feel identifying different pieces of medical equipment when you enter a space? 3

8. Using the scale below, how often do you require assistance from personnel within other department?

0%	25%	50%	75%	100%

a) On average, what is the typical paygrade of the individual assisting you?

E5

Respondent 21

Inventory Management/Bio-Medical Repair Questionnaire

1. What is your current Rate and Paygrade? (e.g., SH3/E4)
   HM2/E-5
2. What is your primary duty? Biomedical repair technician
3. How long have you been performing your current duties? (Please answer in years and months) 3 years, 2 months
4. On average how much of your day is spent looking for equipment? (please provide answer in hours and minutes) 30 minutes
5. On average how much time would you estimate that you spend searching for an **individual piece** of medical equipment? (please provide answer in hours and minutes)
   10 min.
6. What is your best estimate for time spent looking for the following items (i.e. specific serial number)? (please provide answer in hours and minutes)
   - Blood Analyzer - 0
   - Defibrillator - 0
   - Heart Monitors - 0
   - Infusion Pumps - 0
   - Electro Cardiogram (EKG) - 0
   - Vital Signs Machine - 0
7. At what point do you feel that you've exhausted all of your resources in searching for an item listed above and decide to forward the issue up your chain of command? (Please answer in days and hours) After LPO of department can not find the piece of equipment.
8. Rating the equipment from 1 to 5, 1 being unfamiliar, 5 being very familiar, how comfortable do you feel identifying different pieces of medical equipment when you enter a space? 4

8. Using the scale below, how often do you require assistance from personnel within other department?

	X			
0%	25%	50%	75%	100%

a) On average, what is the typical paygrade of the individual assisting you?
   E-5

Respondent 22

Inventory Management/Bio-Medical Repair Questionnaire

1. What is your current Rate and Paygrade? (e.g., SH3/E4)
   HM1 / E6
2. What is your primary duty?
   ADVANCED BIOMEDREPAIR TECH
3. How long have you been performing your current duties? (Please answer in years and months) 2 ~~Yrs~~ YEARS 6 MONTHS

4. On average how much of your day is spent looking for equipment? (please provide answer in hours and minutes)

5. On average how much time would you estimate that you spend searching for an **individual piece** of medical equipment? (please provide answer in hours and minutes)

6. What is your best estimate for time spent looking for the following items (i.e. specific serial number)? (please provide answer in hours and minutes)

   - Blood Analyzer
   - Defibrillator
   - Heart Monitors
   - Infusion Pumps
   - Electro Cardiogram (EKG)
   - Vital Signs Machine

7. At what point do you feel that you've exhausted all of your resources in searching for an item listed above and decide to forward the issue up your chain of command? (Please answer in days and hours)

8. Rating the equipment from 1 to 5, 1 being unfamiliar, 5 being very familiar, how comfortable do you feel identifying different pieces of medical equipment when you enter a space? 4

8. Using the scale below, how often do you require assistance from personnel within other department?

0%	25%	50%	75%	100%

a) On average, what is the typical paygrade of the individual assisting you?
   E6

LIST OF REFERENCES

Under Secretary of Defense (AT&L), Radio Frequency Identification (RFID) Policy, Version 1.0 30 July 2004

Casey, Michael, "New Technology Focuses on Equipment Management", The MC Report, 8 June, 2004

Fanberg, Hank, " The RFID Revolution", American Marketing Association Marketing Health Services, Fall 2004, pp. 43

Want, Roy, "RFID A Key to Automating Everything", Scientific American, January 2004, pp. 60

http://www.aimglobal.org/technologies/rfid/what_is_rfid.asp, 12 November 2004

http://www-nmlc.med.navy.mil/gov_only/default.htm, 24 November 2004

http://www-nmlc.med.navy.mil/gov_only/equipment/equipment.htm, 24 November 2004

NAVMED P-5132

Phone conversation with Stacy Mountford, eXI Wireless Systems Inc., 30 September 2004.

Interview with MR. William Benson, Plant Property and Equipment Manager, NMCSD, 8 October 2004.

Cavoukian, Ann Ph.D, "Tag, You're It: Privacy Implications of Radio Frequency Identification (RFID) Technology", Information and Privacy Commissioner/Ontario Report, February 2004, pp. 14

http://books.nap.edu/html/to_err_is_human/Ch2.PDF, 19 October 2004.

Food and Drug Administration report, "Combating Counterfeit Drugs", http://www.fda.gov/oc/initiatives/counterfeit/report02_04.html#report, January 2004

http://www.dodig.osd.mil/audit/reports/fy04/04-087.pdf, 19 October 2004.

Hasson, Judi; "Blood-tracking Systems Fragmented," September 17, 2001 www.fcw.com/fcw/articles/2001/0917/web-blood-09-17-01.asp

Phone interview with LT Todd Tetreault, Medical Service Corps, USNR, October 27, 2004

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